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DISPOSAL AREA MONITORING SYSTEM

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IV. Mass Balance Calculations

V. Measurement of Geotechnical Properties at the Central Long Island Sound Disposal Site

VI. Submersible and ROV Surveys at Deep Water Disposal Sites in New England

VII. Green Harbor Wave Climate

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VOLUME IV

TABLE OF CONTENTS

VOLUME IV

TABLE OF CONTENTS (CONT.)

IV. MASS BALANCE CALCULATIONS

LIST OF FIGURES

LIST OF TABLES

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V. MEASUREMENT OF GEOTECHNICAL PROPERTIES AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE

LIST OF FIGURES

V. MEASUREMENT OF GEOTECHNICAL PROPERTIES AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE

LIST OF TABLES

VI. SUBMERSIBLE AND ROV SURVEYS AT DEEP WATER DISPOSAL SITES IN NEW ENGLAND

LIST OF FIGURES

SAIC

LIST OF FIGURES (CONT.)

LIST OF TABLES

LIST OF TABLES (CONT.)

LIST OF TABLES (CONT.)

VII. GREEN HARBOR WAVE CLIMATE

LIST OF FIGURES

LIST OF TABLES

SAIC

IV. MASS BALANCE CALCULATIONS

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IV. MASS BALANCE CALCULATIONS

1.0 INTRODUCTION

Since the initiation of the DAMOS program, a major thrust of the study has been the continuous monitoring of the distribution and stability of dredged material at the disposal sites through remote sensing using hydrographic survey techniques. The procedure used to determine distribution and to monitor stability are based on hardware systems and software programs designed to produce extremely precise replicate surveys so that small changes in topography can be determined. These data are then used to evaluate sediment accumulation during disposal, movement after deposition within the vicinity of the mound, or total loss of material from the disposal site.

The topographic changes are measured through repeated surveying of a grid established over the disposal site which generally has a lane spacing of 25 meters. In order to provide adequate precision for the replicate surveys over that grid, the data acquisition system used for this project must meet several design criteria including:

- an accurate positioning system capable of providing precision range measurements to locate the ship within 2 m at ranges up to 40 km

- a flexible survey fathometer system capable of measurements between 10 m and 100 m depth ranges with a capacity for subbottom profiling or plume tracking when required

- a sophisticated helmsman's aid system capable of controlling a relatively large (65-100 ft.) research vessel within ± 5 m of the designated transect lanes

- a rapid and flexible data recording system that can acquire and record all necessary depth and position information within the one second update rate of the position system

- a data processing system that can provide results in a short time, aboard the survey vessel, so that the information can be used to manage disposal operations or to select sampling and measurement locations for monitoring studies

- an overall system flexibility to apply the inherent navigational accuracy of the survey system to other aspects of the monitoring program, such as replicate biologic sampling, instrument and buoy deployment or retrieval, and control of the disposal operation when necessary.

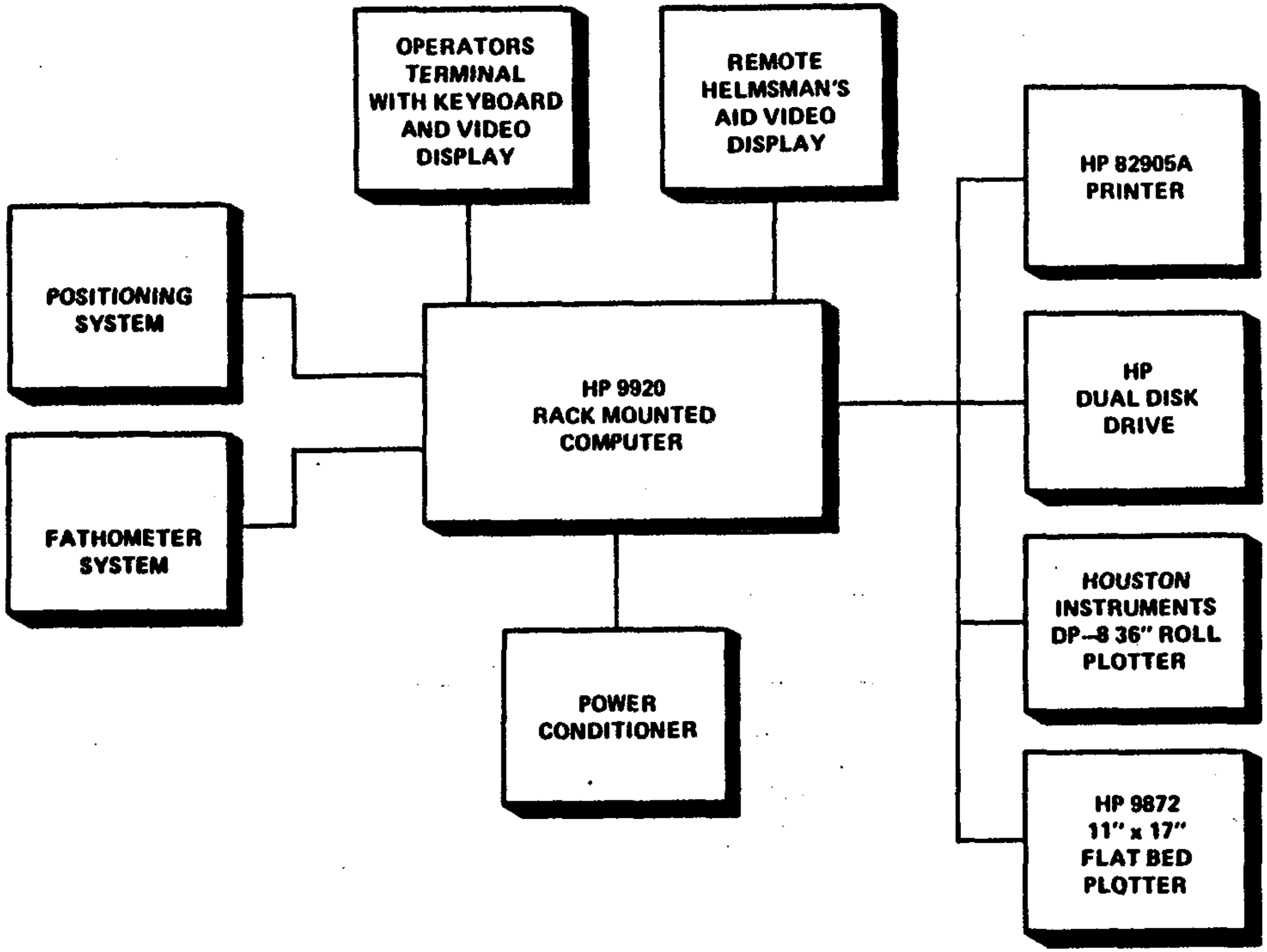
In order to meet these criteria, SAIC has developed a series of navigation and data acquisition systems which have been used on the DAMOS program at all of the disposal sites. The latest version of the system (Fig. IV-1-1) is based on an HP 9920 computer, interfaced to a Del Norte Trisponder positioning unit and either a Raytheon 719D or EDO 274 fathometer.

During the Stamford/New Haven capping operations at the CLIS site in 1979, the replicate survey technique was used with excellent success to measure the distribution and volume of material at the disposal sites and also to document the loss of some capping material from the STNH-S site as a result of Hurricane David during the fall of 1979 (Morton, 1983; Shonting and Morton, 1982). These measurements were accomplished through development of contour grids for each survey and calculation of volume difference between successive surveys by comparison of the gridded data. The difference in depth (ΔZ_i) of each cell between successive surveys was determined by subtraction and then multiplied by the area of the cell to determine the net change in volume. These volume changes were then summed along transects and over the entire grid to determine the total volume change.

Using this technique, the precision of the depth measurement must be extremely high to achieve an accurate volume because small changes in depth are multiplied by the area of the survey. In order to increase this precision, additional corrections were made based on the assumption that no significant changes in depth occur on the natural bottom beyond the extremities of the disposal mound. To make these corrections, the average depth changes ($\Delta \bar{Z}_i$) for all grid locations in the first and last five lanes were determined. If these ($\Delta \bar{Z}_i$) were different from zero, a correction was applied to the third and twenty-third lanes to set those differences to zero. Correction factors for each transect were then determined by linear interpolation between adjacent lanes.

Small differences resulting from errors in tide, sound velocity or draft corrections were thus accounted for and the baselines of successive surveys were accurately aligned with each other. Corrections of this type, while almost always less than 10 cm, were important for increasing the resolution of the volume difference technique.

Previous calculations of errors associated with this procedure (Morton, 1982) indicated that for a 600 m^2 survey with 25 m line spacing, an overall volume difference error of 1200 m^3 would be expected. This estimate appeared to be quite reasonable during the Stamford/New Haven monitoring program as volumes calculated at both the STNH-N and STNH-S averaged approximately 90% of the estimated dredged volumes. However, during subsequent programs at the Foul Area, WLIS III, FVP and at Cap Sites #1 and #2 (Black Rock Harbor sediment which was covered by New Haven material), the agreement between estimated dredged material yardage and that measured at the disposal site by volume difference calculations has not been as close as expected (DAMOS



SAIC NAVIGATION & DATA ACQUISITION SYSTEM

FIGURE IV-1-1

Contributions). Several explanations for this discrepancy have been suggested, including:

- errors in dredged volume estimates resulting from inaccurate measurement of scow yardage

- errors in dredged volume estimates resulting from inaccurate post-dredging surveys caused by the presence of fluff-layers

- errors in the disposal volume estimates resulting from density changes in the dredged material during dredging, transport and disposal operations

- errors in measurement of dredged material volume at the disposal site primarily resulting from inaccuracies in the hydrographic survey procedure

- loss of material during dredging, transport and disposal operations due to leakage, overflow or dispersal.

As a result of the discussions resulting from these discrepancies and their possible causes, a program evaluating the problem of mass balance of dredged material has been initiated under DAMOS. The program has three major areas of study:

- Determination of the accuracy and applicability of the Troxler Nuclear Density Probe for assessment of sediment density.

- Measurement of sediment properties during dredging, transport and disposal.

- Determination of the accuracy of the replicate survey procedure for sediment volume measurements.

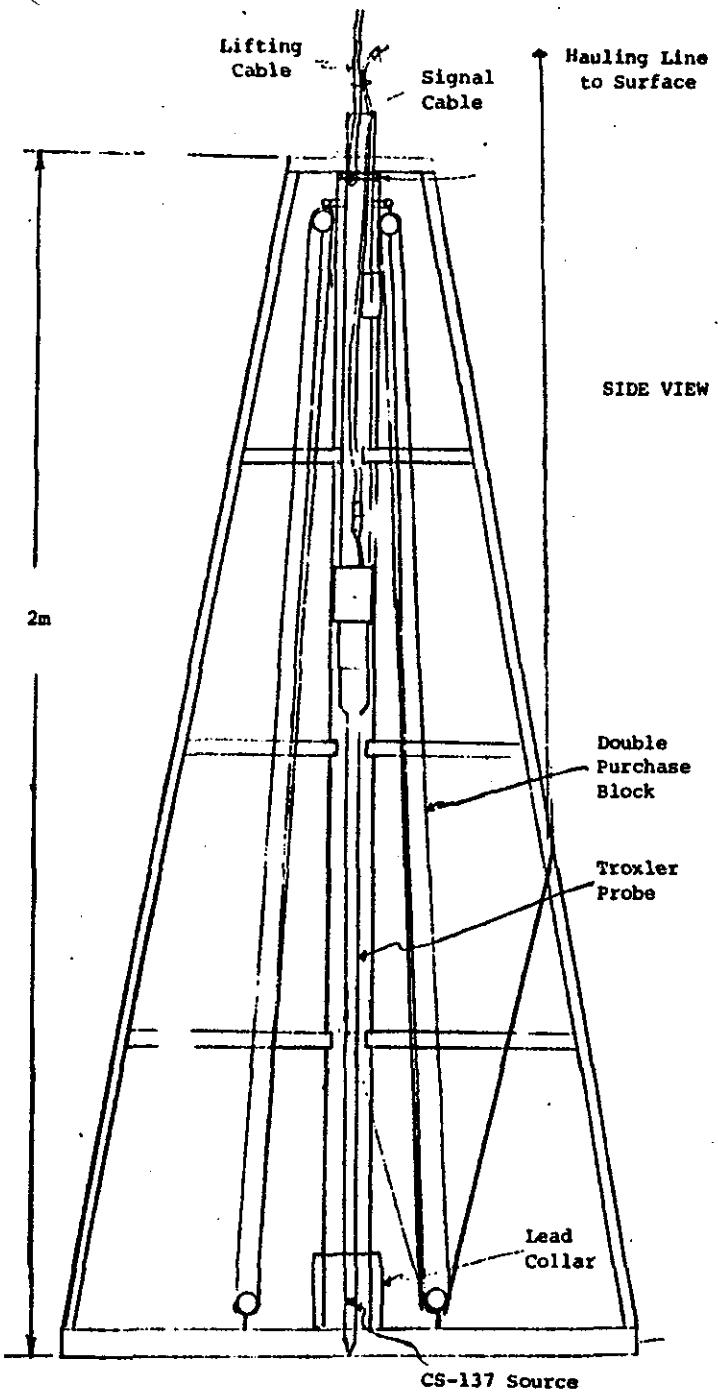
The previous studies mentioned above indicate that most problems associated with mass balance occur with low density, high water content silts and clays. However, since initiation of the program, no projects requiring dredging of such sediments have been scheduled and, consequently, very little has been accomplished on the first two aspects of the program. Most of the work to date has been associated with improvement of sampling and measurement techniques.

2.0 TROXLER NUCLEAR DENSITY PROBE

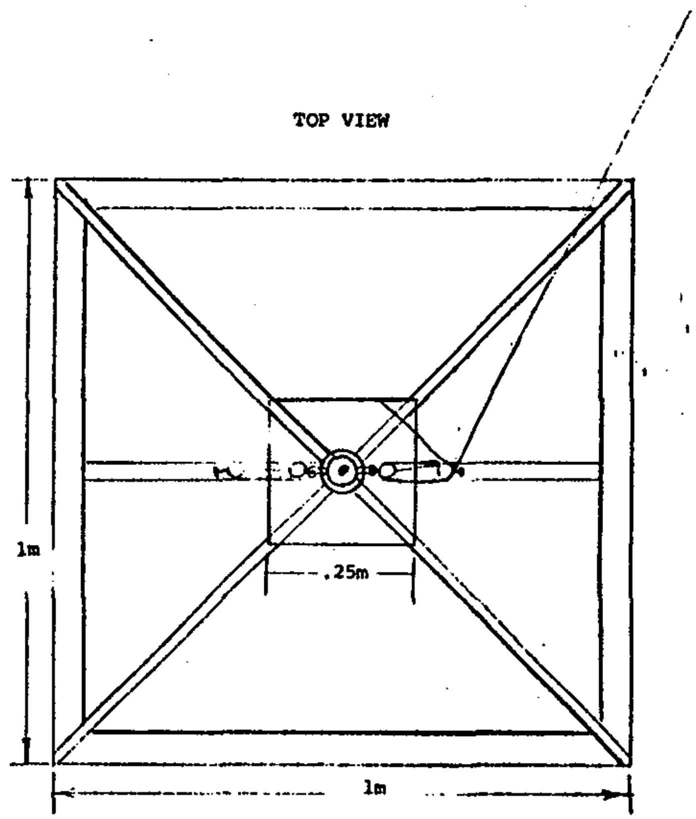
The Troxler Nuclear Density Probe was first used by DAMOS on the capping studies related to disposal of Black Rock and New Haven sediment at the CLIS Disposal Site (Morton et al., 1983). During that program, a deployment frame was developed (Fig. IV-2-1) which was used to control penetration of the probe into the bottom. The deployment frame was operated by Kevlar rope to the surface, which did not provide completely accurate,

FIGURE IV-2-1

SIDE VIEW



TOP VIEW



NUCLEAR DENSITY PROBE

SEDIMENT PENETRATION FRAME

SAIC

measurable data on penetration. Therefore, an engineering program has been initiated to modify the deployment frame using a hydraulic motor to provide power for penetration of the probe. With this system, control of the penetration depth will be much more exact, while flexibility in the sampling operation will be maintained aboard the research vessel.

Preliminary design concepts have been developed at this time and more detailed specifications for the system will be available at the DAMOS symposium in January 1985. The new system will be operational by January 1985 should dredging and disposal operations with appropriate sediment types for mass balance studies be underway.

3.0 GEOTECHNICAL MEASUREMENTS

The second major portion of the mass balance program is concerned with measurement of sediment properties associated with dredging and disposal operations. Dredged materials generally experience a volume change during excavation and during placement or disposal in an aquatic environment. The process of excavation typically results in volume expansion due to sediment mixing with water, whereas disposal results in water pressure gradients within the sediment that lead to time dependent consolidation or densification. These volume changes tend to mask or distort the estimates of dredged material quantitites which are processed on a project since quantities are based upon scow volumes or seismic profiling before and after operations at either the dredging or disposal site. The most reliable method of accounting for dredged material would be to perform mass balance analyses on the basis of the weight of solids (dry weight) transported to the disposal site. More accurate estimates of dredged material could be achieved from a combination of volume, density and water content information.

Volume determinations can be further complicated by losses at each phase of the dredging/disposal process. Depending upon sediment size and gradation, selective winnowing, erosion or size segregation can occur and further cloud a mass balance analysis. Therefore, a proper mass balance analysis should be cognizant of variations in particle size distribution which can be accomplished by coupling such data with dry weights of dredged materials.

The plan for the Geotechnical portion of the Mass Balance Program includes sampling and analysis of sediments from three distinctly different dredging projects with the objective of examining all expected sediment types. Laboratory measurements of water content, bulk density and specific gravity will be used to calibrate and verify in-situ measurements with a nuclear-density probe. These data will also be used to determine the dry weight from the relationship for dry unit weight

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + \omega}$$

where γ_{wet} is wet unit weight and ω is water content. This relationship is important since the dry weight of the sediment that is dredged, transported and deposited would be constant for each phase of the operation if there are no losses of sediment.

In order to assess the quantity of sediment loss associated with clamshell dredging, scow transport and dredged material deposition at a disposal site requires an evaluation of sediment gradation changes. The uncertainties resulting from variation in dredged material type over a dredging site and with depth will necessitate that a large number of samples be tested and that statistical parameters be developed to define spatial variations in grain size and other physical properties at the dredge site, within the scow, and at the disposal site.

One important aspect of such a program that must be fully evaluated is the effect of sampling on sediment parameters. Undisturbed sediment samples are extremely difficult, if not impossible, to obtain and, furthermore, transport of samples from the research vessel to the laboratory can create additional sources of error. Therefore, prior to sampling ongoing dredging and disposal operations, a program has been initiated to address the errors associated with sampling and laboratory analysis of geotechnical properties. Results of that program are presented in Section V of this volume.

4.0 BATHYMETRIC SURVEY MEASUREMENTS

The projects described above are necessary to assess the changes in sediment properties associated with dredging and disposal, but are relatively expensive procedures that are not readily applicable to a disposal monitoring program. Therefore, the remote sensing of dredged material volume by bathymetric survey techniques remains as the most viable approach to monitoring, particularly relative to post-disposal stability of the material.

However, it is apparent from the above discussions that there are many factors affecting the volume of material at the site, and if they are to be evaluated with confidence, the errors associated with the hydrographic measurements must be fully known. In order to achieve this objective, a parametric study of the procedure was initiated using the FVP mound at the CLIS disposal site for assessment of both survey and analytical errors.

4.1 Field Measurements

Two survey grids were established covering the area of the FVP disposal mound with a lane spacing of 25 meters as is customary with most DAMOS surveys. One grid (Fig. IV-4-1) was aligned in an east-west direction, while the other (Fig. IV-4-2) was oriented north-south. In order to complete the surveys within a two day period, the grids were smaller than typical DAMOS surveys, consisting of 19 lanes 300 m long rather than 25 lanes 800 m long. This reduction should not affect the assumption of no depth change beyond the margin of the mound, as the topographic feature associated with the site is only 150 m in diameter.

In order to evaluate the precision of the survey technique, three surveys were run over the east-west grid on the same day. The accuracy of the technique was measured by running the north-south survey grid over exactly the same area on the following day.

The surveys were conducted aboard the R/V UCONN, the vessel commonly used for DAMOS surveys in Long Island Sound. The crew aboard this vessel is very experienced in running survey grids and, consequently, positioning errors caused by off-track deviations were minimized. The Del Norte trisponder system was fully calibrated over a known range between Pt. Judith and Beavertail Lighthouses in Rhode Island on the day before the surveys, and this calibration was checked in the usual manner by a baseline crossing between the New Haven and Stratford Point Lighthouses during transit to and from the site each day. A bar check was performed on the Raytheon 719D fathometer system before and after each survey and the SSD-100 digitizer was adjusted to agree with the fathometer trace. The transducer was then fastened to the side of the ship in its standard configuration one meter below the surface of the water. All data were input to the SAIC Navigation and Data Acquisition System and recorded at 1 second intervals on disk storage.

4.2 Data Analysis

Data disks were returned to the laboartory and analyzed on the same HP 9920 computer through an updated version of the analysis procedures described in Morton (1983). Tidal corrections were applied to each survey through a subroutine which calculates a continuous tidal curve from NOAA Tide Table data. A draft correction of one meter was also applied before analysis.

Following corrections to the measured depth values, the data were entered into a gridding subroutine which is used for contouring and subsequent volume difference calculations. Previous DAMOS surveys have used a standard convention where the grid size is specified as half the distance between lanes along the lane and equal to the distance across the lane with the center of the grid cell located on the lane. This spacing is considered most practical since resolution of depth between lanes

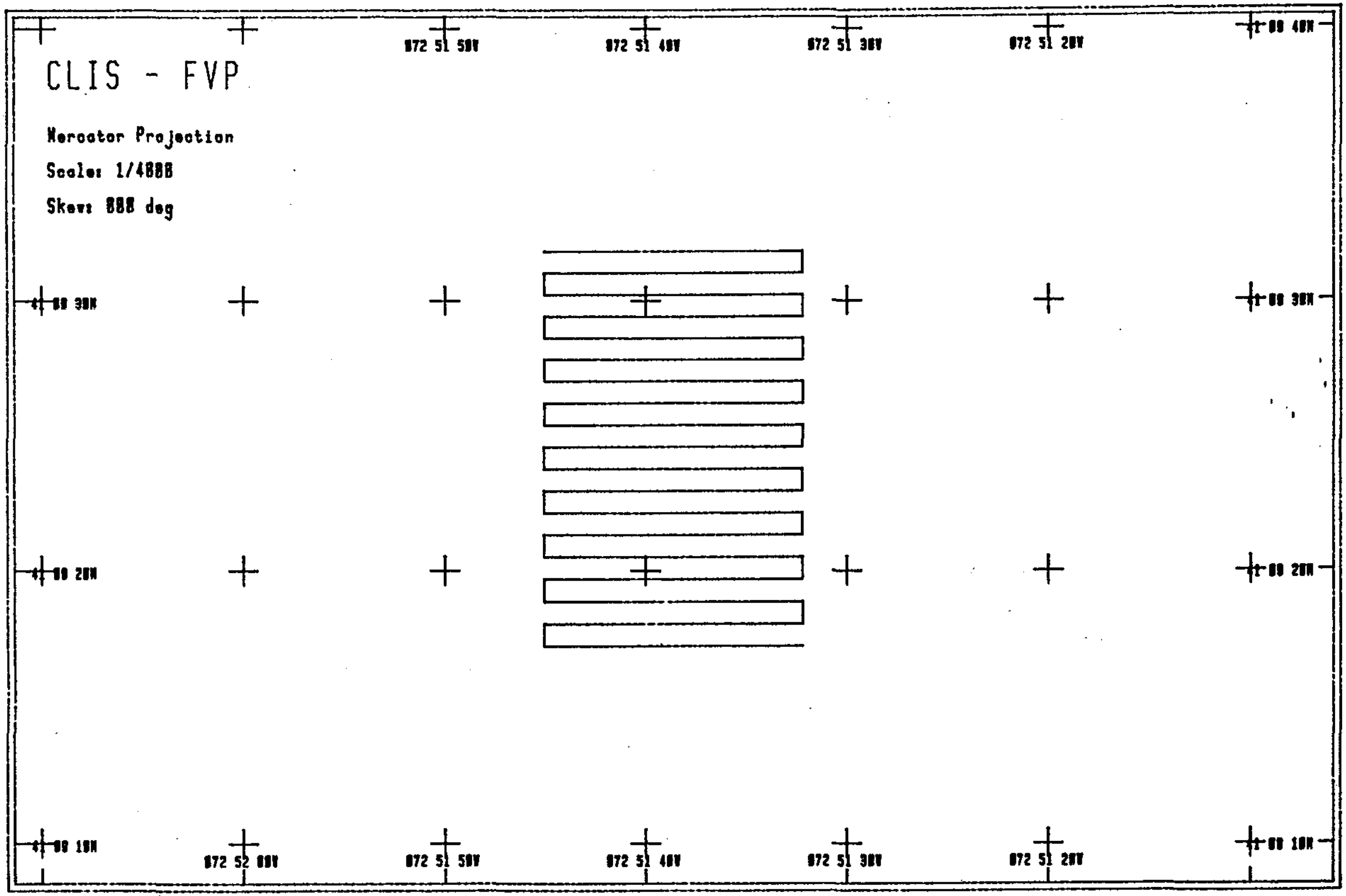


FIGURE IV-4-1. Survey grid at FVP disposal mound (East-West).

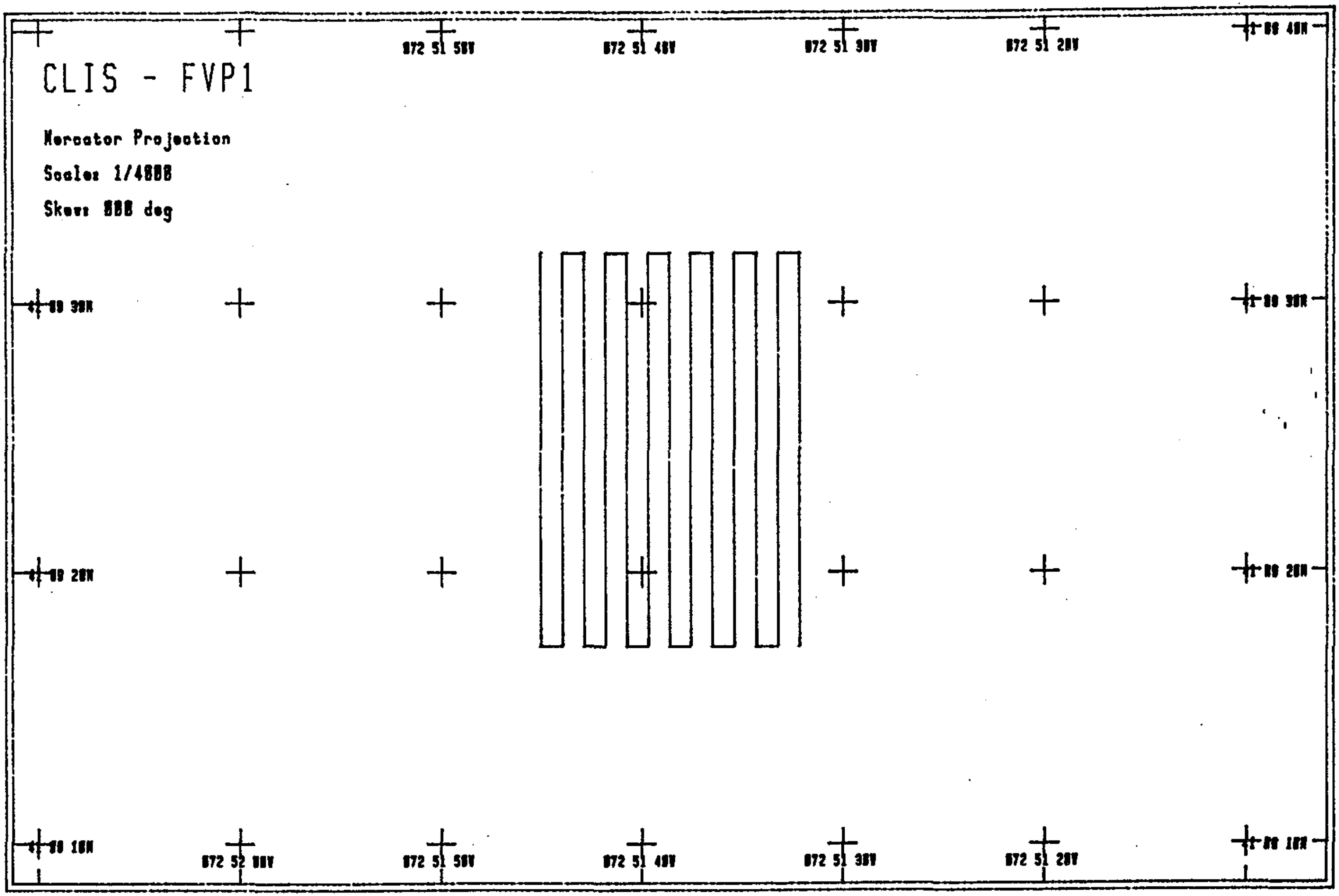


FIGURE IV-4-2. Survey grid at FVP disposal mound (North-South).

cannot be improved and increased resolution along the lane would only bias the data in that direction. However, in order to assess the effect of differing grid schemes on analytical accuracy, three grid resolutions were implemented such that the cell dimensions along the lane were one quarter (6.25 m), one half (12.5 m) and equal to (25 m) the lane spacing. In all cases, the cross-transect dimension was 25 m.

All depths falling within a grid cell are used to compute a weighted average depth which is assigned to the location of the center of the cell. The weight applied to each measurement is a function of its distance from the center, such that a point located at the center would have a 100% weight and a point on the border of the cell would have a 10% weight. This weighted average approach is an improvement over earlier gridding procedures which treated all values equally.

Calculation of volume difference between surveys is accomplished in essentially the same manner as described in Morton (1980), however some refinements have been made in the procedure to improve corrections for depth differences between surveys. Volume calculations are accomplished by first subtracting depths on a cell by cell basis between surveys. Once the matrix of depth differences is generated, corrections for small errors between surveys can be made based on the assumption that no significant depth differences occur on natural bottom beyond the margins of the disposal mound. Earlier corrections were based on comparison of the first and last three to five lanes of the survey using linear interpolation to correct the depths of lanes in between. A different approach has been used on DAMOS surveys over the past two years, where the center of the survey is essentially windowed and depths from all cells surrounding the window are used to calculate corrections. All depths from the margin area are compiled as a function of lane number and a least squares fit of all data is calculated. Corrections for each lane are then derived from the least squares curve.

Volume differences between surveys are then computed based on subtraction of the corrected grid cells between surveys. As a general rule, the earlier survey is subtracted from the later survey and, since in this case positive values would indicate loss of sediment, the result is multiplied by (-1) times the area of each cell, and summed over the total number of cells to determine the total volume of material added or lost to the site.

4.3 Error Analysis

An estimate of the errors associated with the replicate survey technique can be made using standard error analysis procedures. However, when making these error estimates, it is extremely important to differentiate between bias and random errors. Bias errors are those which occur over a period of time and apply to all measurements within a given survey, while random errors occur over a short period of time and are potentially different for each depth measurement. Examples of bias errors include:

- calibration errors in navigation or fathometer systems
- positioning errors caused by transducer-antenna offsets
- errors in draft correction, possibly caused by different fuel loads on the research vessel
- tidal correction errors possibly caused by differing run-off conditions.

Examples of random errors include:

- depth measurement errors caused by sea and swell conditions
- position errors caused by cross-track steering uncertainties
- instrumentation resolution errors, including truncation or rounding of data entries

The objective of the lane by lane depth correction described in the previous section is to remove the bias errors. When this analytical technique is combined with standard operating procedures which include permanent installation of transducer and antenna mounts, daily calibration of navigation and fathometer systems, as well as computerized survey set-up calcuations, the bias errors are minimized to such an extent as to be minimal and undetectable.

Random errors, on the other hand, can not be controlled or reduced through operational or analytical procedures and must be addressed separately. To arrive at an estimate of the random errors, they must be examined in terms of the formula for volume difference calculations:

$$V_o = A\,(\overline{Z}_2 - \overline{Z}_1) \qquad (1)$$

where $\overline{Z}_1$ and $\overline{Z}_2$ are the average depths for the two surveys and is the total survey area. Then the differential volume difference that might occur as the result of errors in measurement would be

$$\delta V_o = A\,(\delta Z_2 - \delta Z_1) \qquad (2)$$

or in terms of potential errors

$$\varepsilon_v = A\,(\varepsilon_2 - \varepsilon_1) \qquad (3)$$

where ε_v is the total error in volume difference caused by the errors of each survey ε_1 and ε_2. To determine the standard error estimate for the volume difference, equation 3 is squared and ensemble averaged such that

$$<\varepsilon_v^2> = A^2 (<\varepsilon_2^2> + <\varepsilon_1^2>)$$

and since the random errors from survey one are independent of survey two, then $\varepsilon_1^2 = \varepsilon_2^2$ and

$$\sigma_v = A \sqrt{\sigma_2^2 + \sigma_1^2} = A \sqrt{2}\, \sigma \qquad (4)$$

If there are M grid cells in the survey, then

$$\sigma = \frac{\sigma_c}{\sqrt{M}}$$

where σ_c is the standard deviation of the depth error for any given cell. Likewise,

$$\sigma_c = \frac{\sigma_r}{\sqrt{N}}$$

where σ_r is the standard deviation of all measured depths within a cell. σ_r must be estimated to evaluate the total error of the survey procedure. Using specifications of the survey fathometer system, errors on the order to $\pm$10 cm or less can be expected from instrumentation. Based on observed slopes of 2.5 to 5 cm/m at disposal mounds and cross-track errors of less than $\pm$5 meters, then worst case depth errors due to navigation are in the range of 10 to 20 cm. Since all precision surveys are conducted under nearly calm conditions, the impact of wave action must be minimal, or approximately 10 to 25 cm. By calculating the root mean square for these errors, then σ_r can be estimated as between 17 and 33 cm.

For a ship moving at 8 knots, the number of points per cell will vary from six on a 25 m grid to 1.5 on a 6.25 m grid and, therefore, σ_c can vary from 7 to 27 cm depending on the grid used and the estimate of σ_r.

Calculation of σ also depends on the grid size used and, for the surveys run of this program, the number of cells can vary from 247 for a 25 x 25 m cell, to 988 for a 6.25 to 25 m cell. Based on these numbers, σ can vary from .44 cm for a 25 m grid and minimal measurement error to .85 cm for maximum measurement error and a 6.25 m grid.

It should be pointed out, however, that the grid size has no impact on calculation of σ. Assuming the minimum σ_r of 17 cm for a grid spacing of 25 m,

$$\sigma_c = \frac{17}{\sqrt{6}} = 7 \text{ and } \sigma = \frac{7}{\sqrt{247}} = .44 \text{ cm},$$

while for a grid spacing of 6.25 m,

$$\sigma_c = \frac{17}{\sqrt{1.5}} = 13.9 \quad \text{and} \quad \sigma = \frac{13.9}{\sqrt{988}} = .44 \text{ cm.}$$

Once σ has been calculated, the total standard deviation of the volume difference σ_v can be calculated as shown in Equation 4) by multiplying σ by the area of the survey times $\sqrt{2}$. Thus, for these surveys, the expected range error could range between 833 m^3 and 1622 m^3. If the same error bounds were applied to a full size DAMOS survey, then the total error would range between 1050 m^3 and 2024 m^3. Assuming a 60,000 m^3 disposal operation, these errors are approximately 1.5 and 3% of the total volume present at the site.

Based on this analysis, the accuracy of the volume difference calculation is primarily dependent on the total number of depth measurements obtained on a given survey. At the present time, the system obtains a single measurement of depth each second. If the frequency of measurements could be increased, then the standard error could be reduced. One potential technique to accomplish this would be to average the depths measured over the one second interval. Since the SSD-100 digitizer can output depth 10 times per second, the measurement error σ_r could be reduced by $1/\sqrt{10}$ or by approximately 1/3. Such reductions depend on the independence of each measurement, which may not be completely true as the sample rate increases.

4.4 Results of Field Surveys

The surveys conducted over the FVP disposal site were analyzed using standard DAMOS procedures to determine whether or not the error estimates developed in the previous section are in fact realistic. Each of the three east-west surveys (FVP 1, 2 and 3) was gridded at cell resolutions of 25, 12.5 and 6.25 m along the survey lanes. The north-south survey (FVP-4) was only gridded at a 25 m cell size since a square grid configuration is the only set up that will provide a direct comparison of individual cells while retaining correct resolution between survey lines.

Contour charts of the 25 x 25 m grids are presented for the three east-west surveys as Figures IV-4-3 a, b and c, and for the north-south survey as Figure IV-4-4. Similarly, contour charts of the FVP-1 survey at 25, 12.5 and 6.25 m grid resolution are presented as Figure IV-4-5 a, b and c. On a survey this small, the 25 x 25 m grid cells do not provide a great deal of resolution, but do indicate the overall shape of the disposal mound and absolute depth offsets that may occur.

In general, it is apparent that all four surveys have delineated the mound with the same general shape and relative thickness. All surveys show a thickness of 1.2 meters, although the absolute depth of the north-south mound on the second day is approximately .6 m deeper than the east-west surveys.

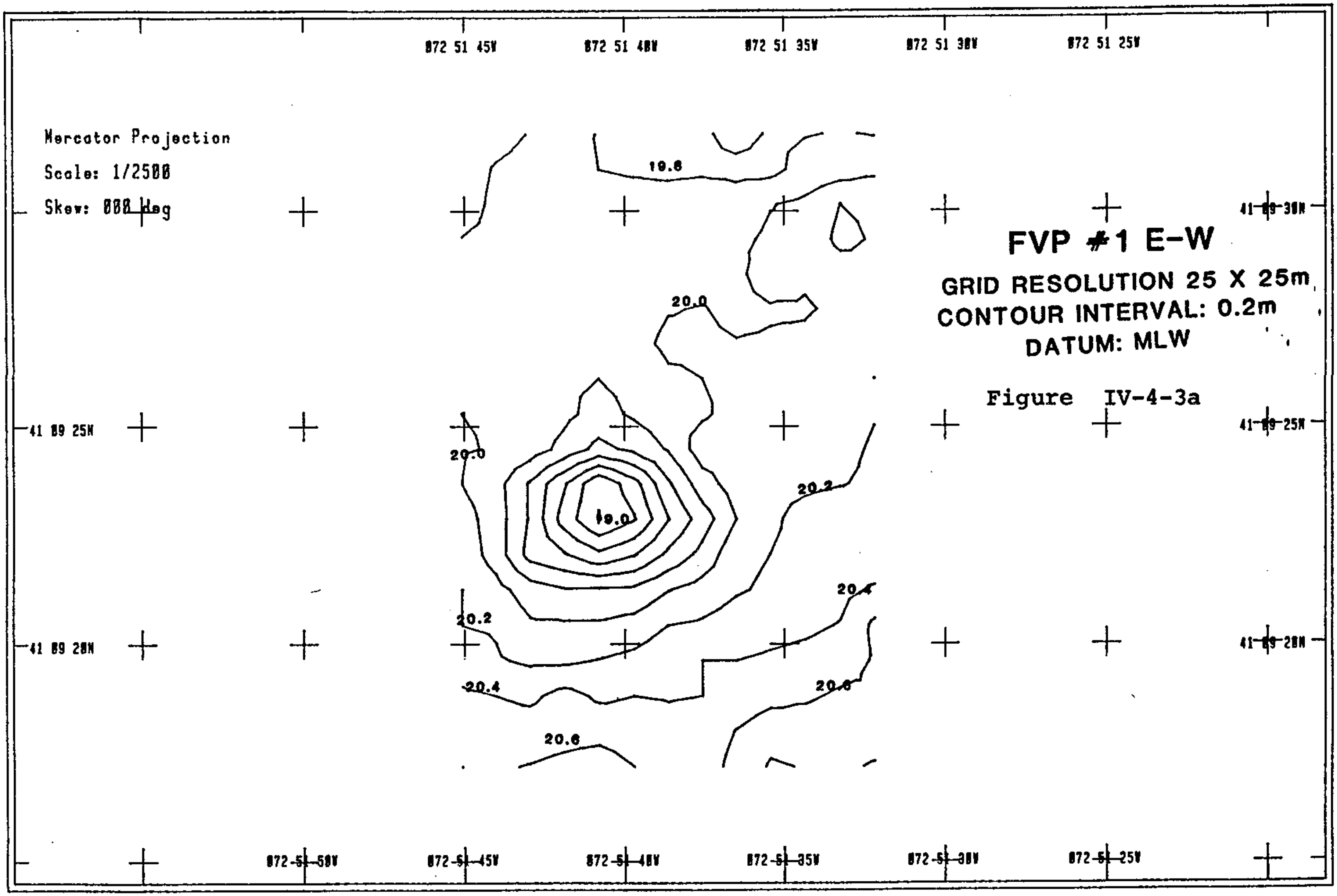


Figure IV-4-3a

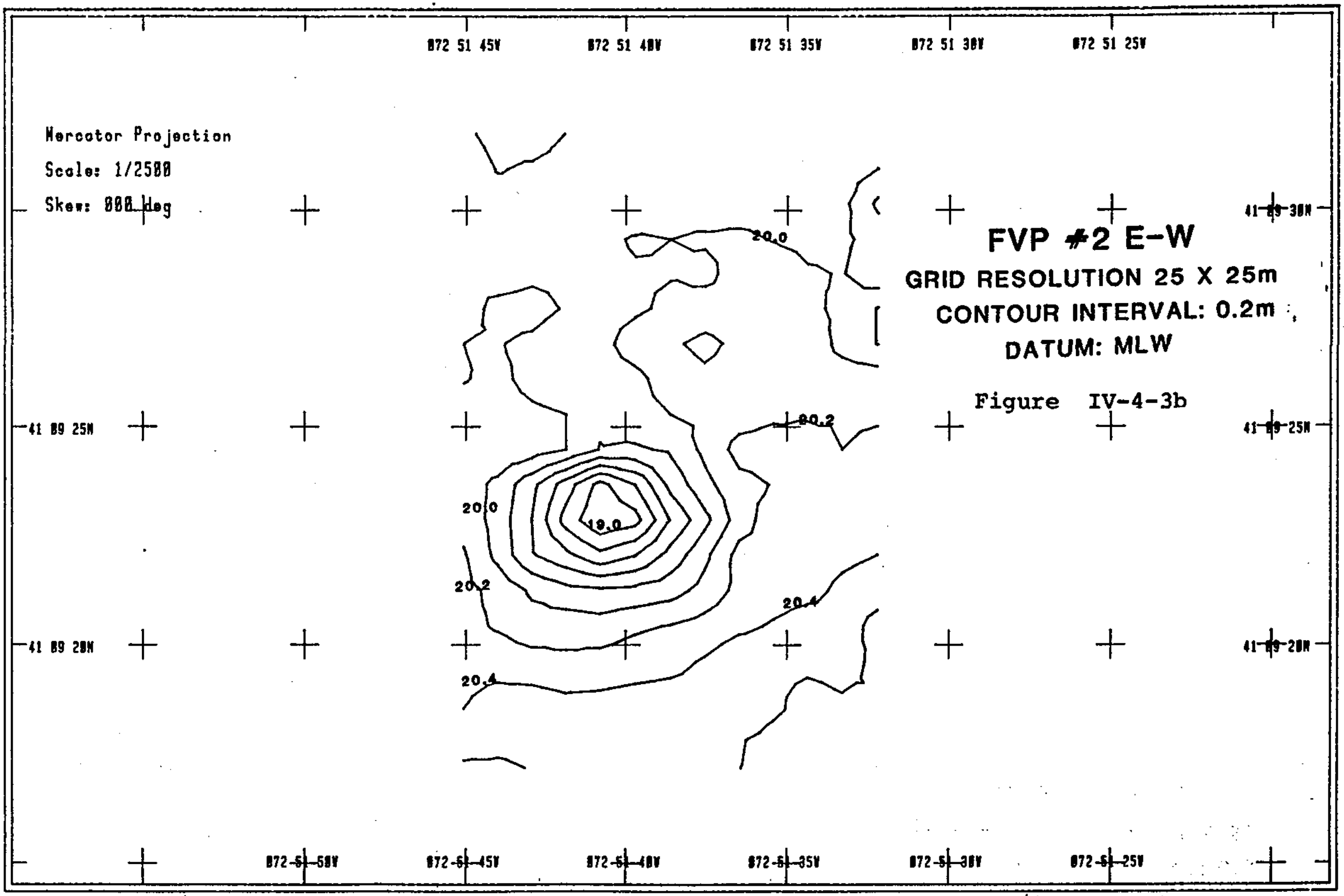
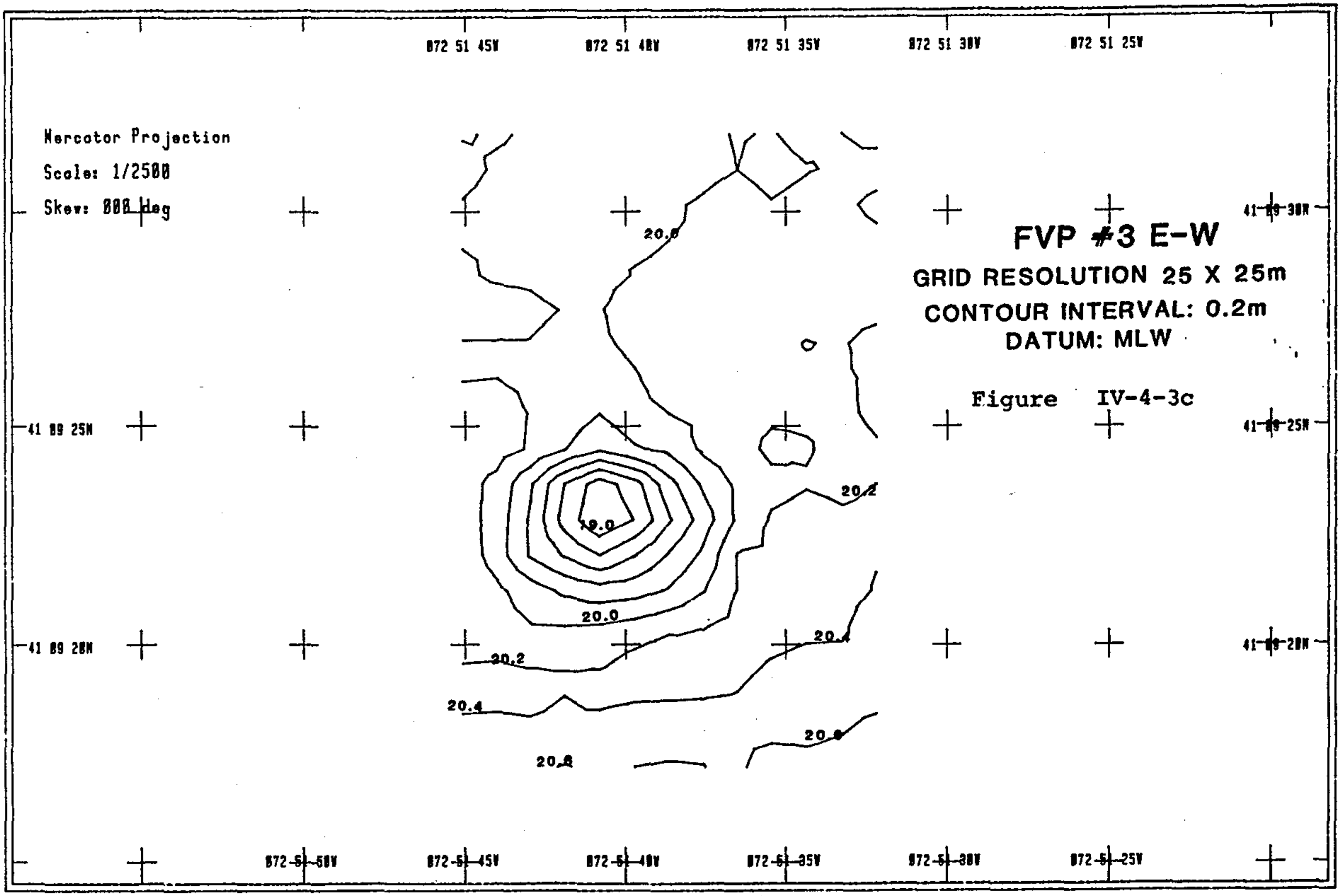


Figure IV-4-3b



FVP #3 E-W
GRID RESOLUTION 25 X 25m
CONTOUR INTERVAL: 0.2m
DATUM: MLW

Figure IV-4-3c

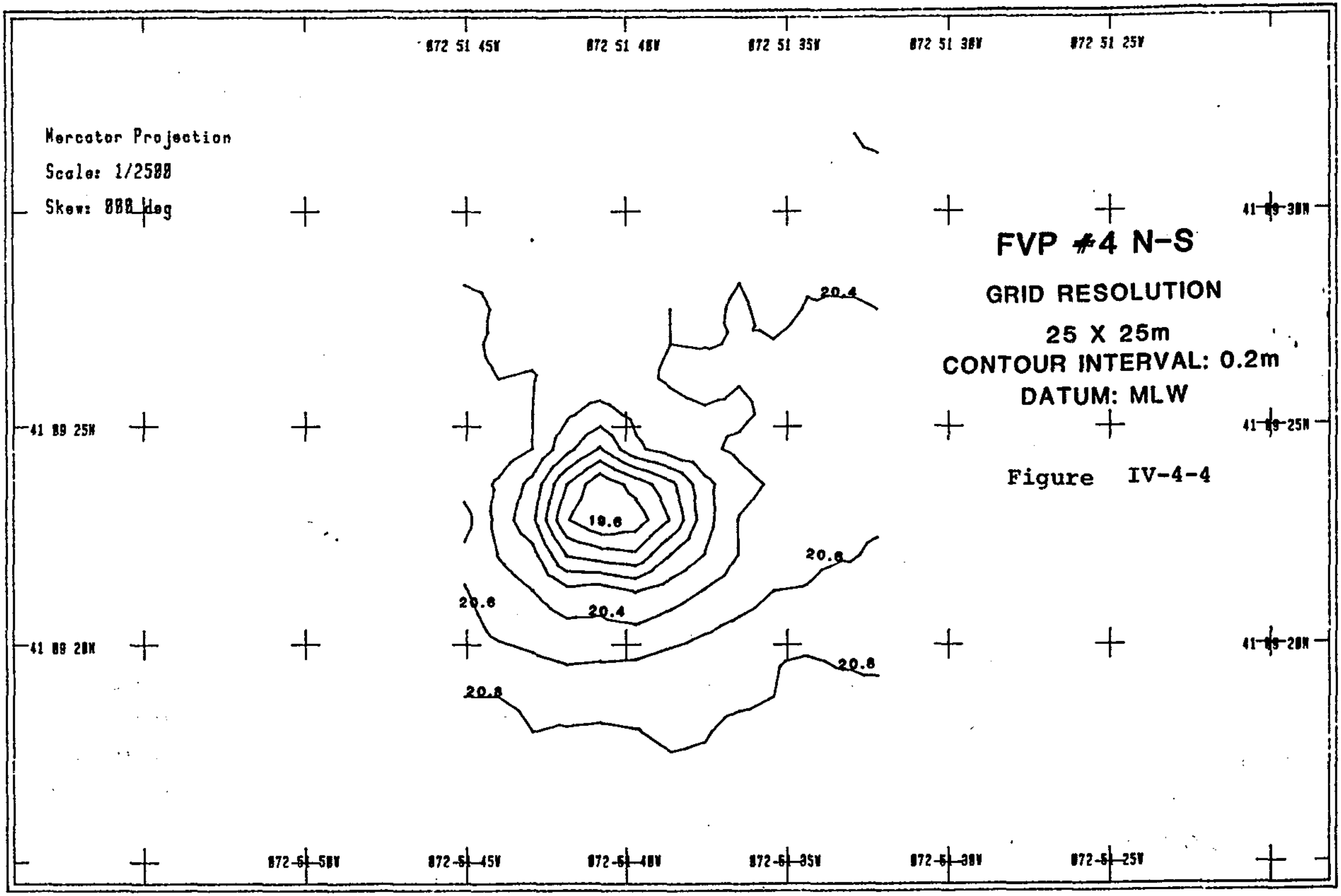

072 51 45W
072 51 40W
072 51 35W
072 51 30W
072 51 25W
Mercator Projection
Scale: 1/2500
Skew: 000 deg
41 09 30N
41 09 25N
41 09 20N
FVP #4 N-S
GRID RESOLUTION
25 X 25m
CONTOUR INTERVAL: 0.2m
DATUM: MLW
20.4
19.6
20.6
20.4
20.6
20.8
20.8
072-51-50W
072-51-45W
072-51-40W
072-51-35W
072-51-30W
072-51-25W

Figure IV-4-4

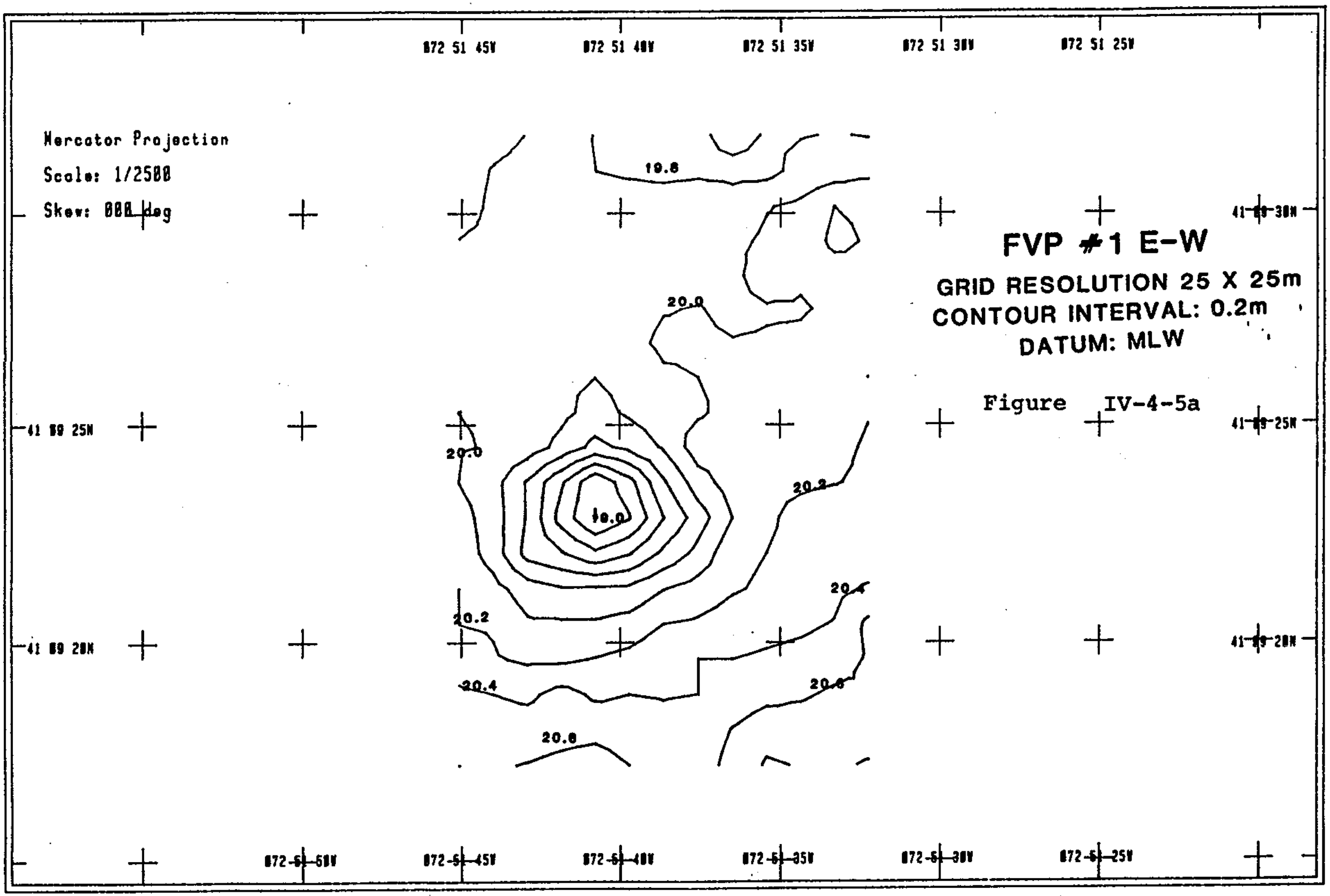


Figure IV-4-5a

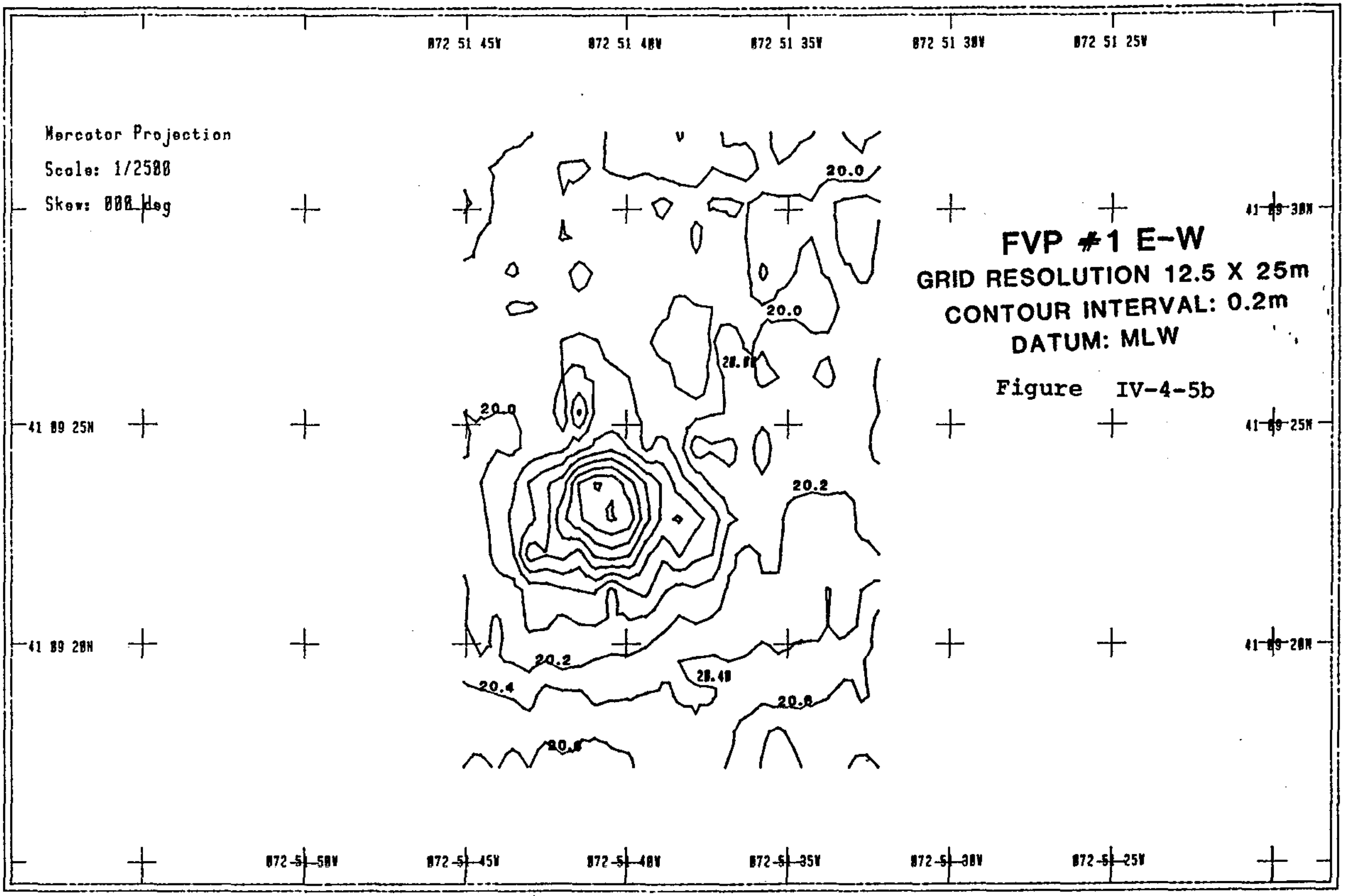


Figure IV-4-5b

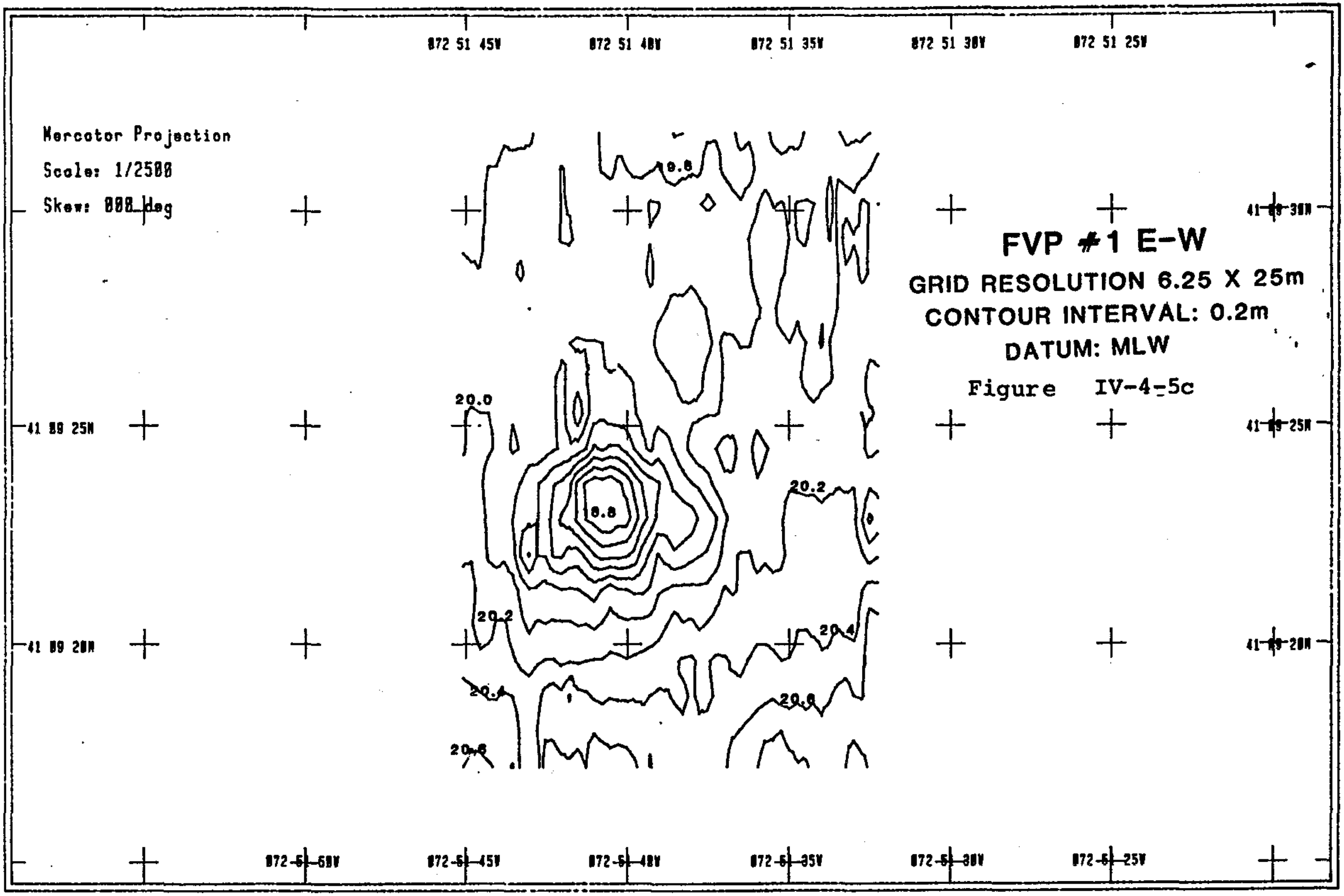


Figure IV-4-5c

Furthermore, survey FVP #2 does not show the northern extension of the 20.2 m contour that is evident on all other surveys. While the absolute depth difference is probably a calibration error and can be eliminated, the depth error on the north side of the mound probably results from a navigation or survey error and cannot be corrected. This may, in fact, be a small error, since it occurs at the base of the mound, where slopes are relatively low and thus small depth changes result in large position changes in contour lines.

Comparison of the resolution achieved by finer gridding is apparent in Figures IV-4-3a, b and c. The coarse grids shown in "a" are really not adequate to characterize the shape of the mound, and the elongation of features caused by the 6.25 x 25 m grid in "c" are certainly distortions of the true depth contours caused by interpolation between lanes. Therefore, the 12.5 x 25 m grid shown in "b" remains as the best compromise between resolution and presentation of the data.

Several volume difference calculations have been made on these surveys varying the different parameters to evaluate their effect on the results. At this time, a full analysis has not been completed, but several conclusions can be drawn. The first matrix of volume differences between the surveys is presented below as Table IV-4-1.

The most obvious feature of these early results is their agreement with expected errors developed in Section 3 of this report. Furthermore, there is consistency in the results; FVP 2 and 3 differ markedly from FVP 1 and 4, having a loss of 1000 m^3 of material, but differ only slightly from each other. Likewise, FVP 1 and 4 are quite close. Consequently, it appears at this time that the precision and accuracy of the approach are about equal, since no significant differences were found between the east-west and north-south surveys.

Further investigation into the analysis procedures indicates, however that more accuracy and precision can be gained with additional work on the software developed for computation of volume difference. Tests are now being run on idealized data to verify these improvements.

Table IV-4-1

Preliminary Volume Differences
Between FVP Surveys

	FVP-1	FVP-2	FVP-3
FVP-1	X		
FVP-2	-1010	X	
FVP-3	-1004	6.0	X
FVP-4	83	902	1170

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V. MEASUREMENT OF GEOTECHNICAL PROPERTIES AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE

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V. MEASUREMENT OF GEOTECHNICAL PROPERTIES AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE

1.0 INTRODUCTION

Seven mounds of dredged material have been created at the Central Long Island Sound (CLIS) disposal site. This site is located about seven miles south of the mouth of New Haven Harbor in water depths of about 20 meters. The mounds contain dredged material from the central and western Connecticut coastal regions. Most of the material can be classified as organic silt. While the physical and engineering properties of dredged materials at the CLIS site have been shown to be similar, they contain organic matter contents about twice that of natural bottom sediments. The amounts of sand and clay also vary between mounds and within a given mound.

The mounds have been in place for two or more years, with the oldest mounds deposited in the Spring 1979. All of the mounds have had a chance to strengthen through consolidation. Four of the mounds have been capped with clean dredged material and the cappings should further strengthen and densify the dredged material.

The objective of this study was to examine strength and density characteristics of sediments from five of the mounds and the natural seabed. This was accomplished onboard ship to minimize sample disturbance that would normally result from core handling and storage during a laboratory testing program. Disturbance associated with the thick-walled gravity corers used in this study probably affect the strength measurements to some unknown degree but because of the low permeabilities and cohesive nature of the sediments at the CLIS site, sample disturbance is not expected to affect the measurement of water content and density. These results should provide some quantitative information about mound stability and density variations that have resulted from geostatic consolidation and also provide background information for mass balance analyses in the future.

2.0 CORING PROGRAM

A total of twelve gravity cores were acquired from the CLIS site. Pertinent core data are summarized in Table V-2-1 including mound site, location within the mound and sample recovery. Cores were obtained from cap site one (CS-1), cap site two (CS-2), the Stamford-New Haven north and south mounds (STNH-N and STNH-S), the Field Verification Program (FVP) site and from the natural bottom at the locations shown in Fig V-2-1. Most of the cores were acquired from the center of a mound with only one core from the mound perimeter and one core from natural bottom. Corer penetration of the mounds and seabed was generally very good, although in the sand capped mounds the recovered sample lengths were typically 1 or 2 meters which was less than 50% of

TABLE V-2-1

SUMMARY OF CORING PROGRAM

Site	Location	Length/ Penetration (m)
CS-1	CTR	.70/3.5
Cs-2	CTR	1.60/?
CS-2	CTR	2.20/?
CS-2	CTR	1.25/?
STNH-S	CTR	1.50/?
STNH-S	CTR	.80/4.5
STNH-N	CTR	.83/?
STNH-N	CTR	1.18/
FVP	CTR	1.60/4.60
FVP	200 E	1.90/4.60
FVP	CTR	1.48/?
Natural Bottom	Between FVP&STNH-N	2.3/4.5

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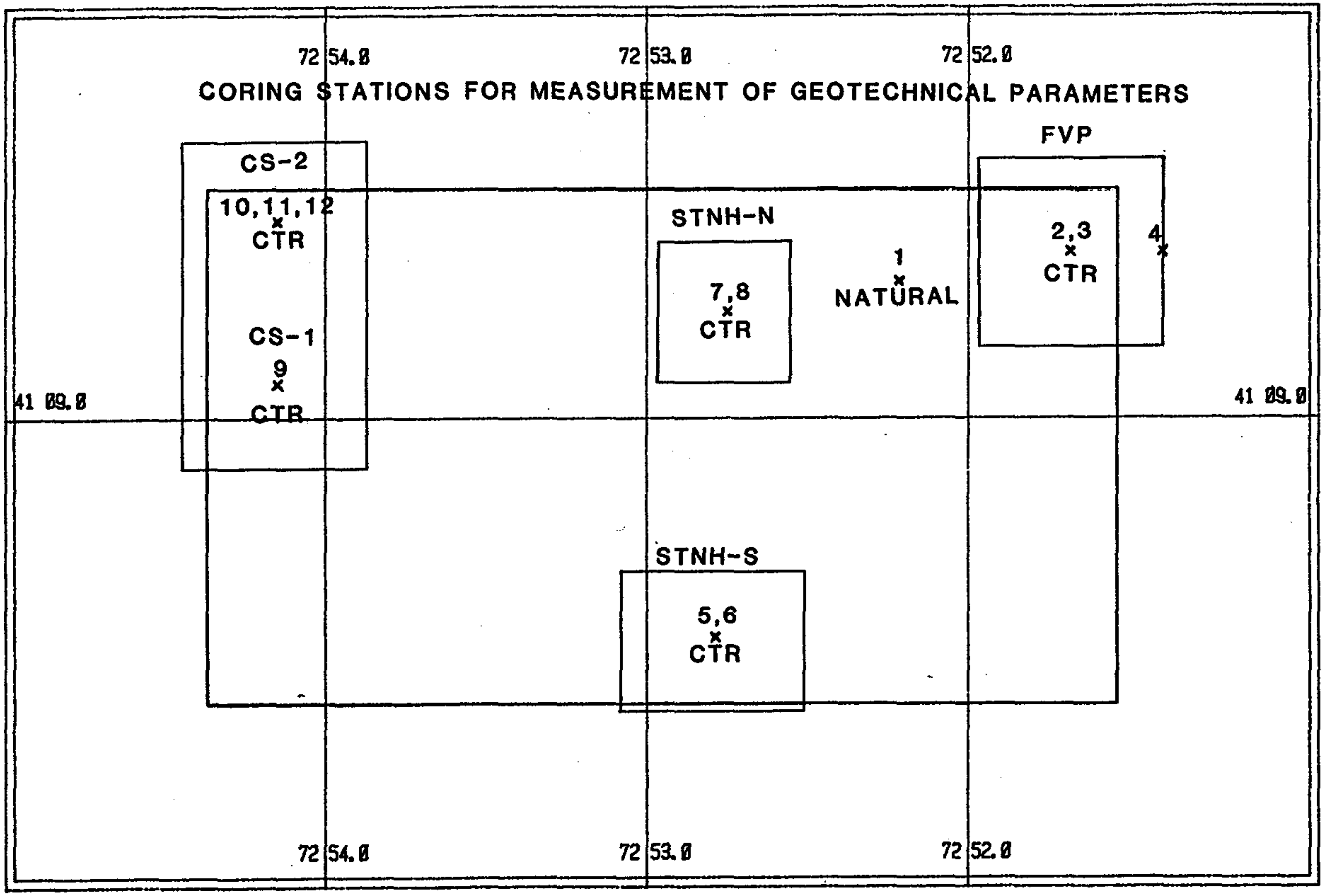

FIGURE V-2-1. Station locations for sediment cores.

seabed penetration. The longest recovered core lengths were from uncapped FVP mound, natural seabed and the silt-capped portion of the CS-1 mound. Thus, corer penetration and sample recovery appears to be related to cap and dredged material sediment type and/or strength factors.

3.0 SEDIMENT TESTING

Following removal from the gravity corer, all samples were split longitudinally on the ship's deck using a power saw and specially designed jig to guide the saw. Shipboard testing of split core samples was usually completed within one hour following coring so there was little change for properties variations from storage or temperature changes. However, all cores are expected to exhibit varying levels of disturbance that are inherent from the geometric features of most marine corers. Split cores were logged to identify the layers of capping and dredged materials and natural bottom sediment as well as zones of mixing between these basic layers. A fall cone penetrometer was then used to estimate the undrained shear strength of cohesive layers at depth increments of about 10 to 20 cm or on each side of a stratigraphic boundary, as appropriate. Ship movement had little effect on strength measurements in the calm waters at the CLIS site, however, ship engine vibrations during movement from station to station had a slight effect (10 to 15%) on cone penetration measurements on the very soft sediments in upper 50 cm of core sediment. Strength measurements were generally halted during ship movement to minimize these vibration effects. The fall cone was typically used three times on each specimen and the strength results were averaged. Several of the cores were remolded and again tested with the cone, so that sediment strength to remolded sediment strength could be determined. These sensitivities provide a basis for assessing sample disturbance since laboratory tests of normally consolidated samples show that the CLIS dredged materials and natural bottom sediments have a sensitvity of about 3.0. About 20 cm of sediment was removed from each strength specimen and placed in a preweighed water content can which was tighly sealed for laboratory measurement of water content.

4.0 TEST RESULTS AND ANALYSES

Shipboard and laboratory data for each of the 12 cores are presented in Figures V-4-1 to 12. Each figure contains a brief description of a core followed by profiles of void ratio and undrained shear strength for cohesive sediments. Void ratios (e) were estimated from water content measurements using the relationship

$$e = \frac{wGs}{S}$$

where S=saturation (taken as 100%), w=water content in percent

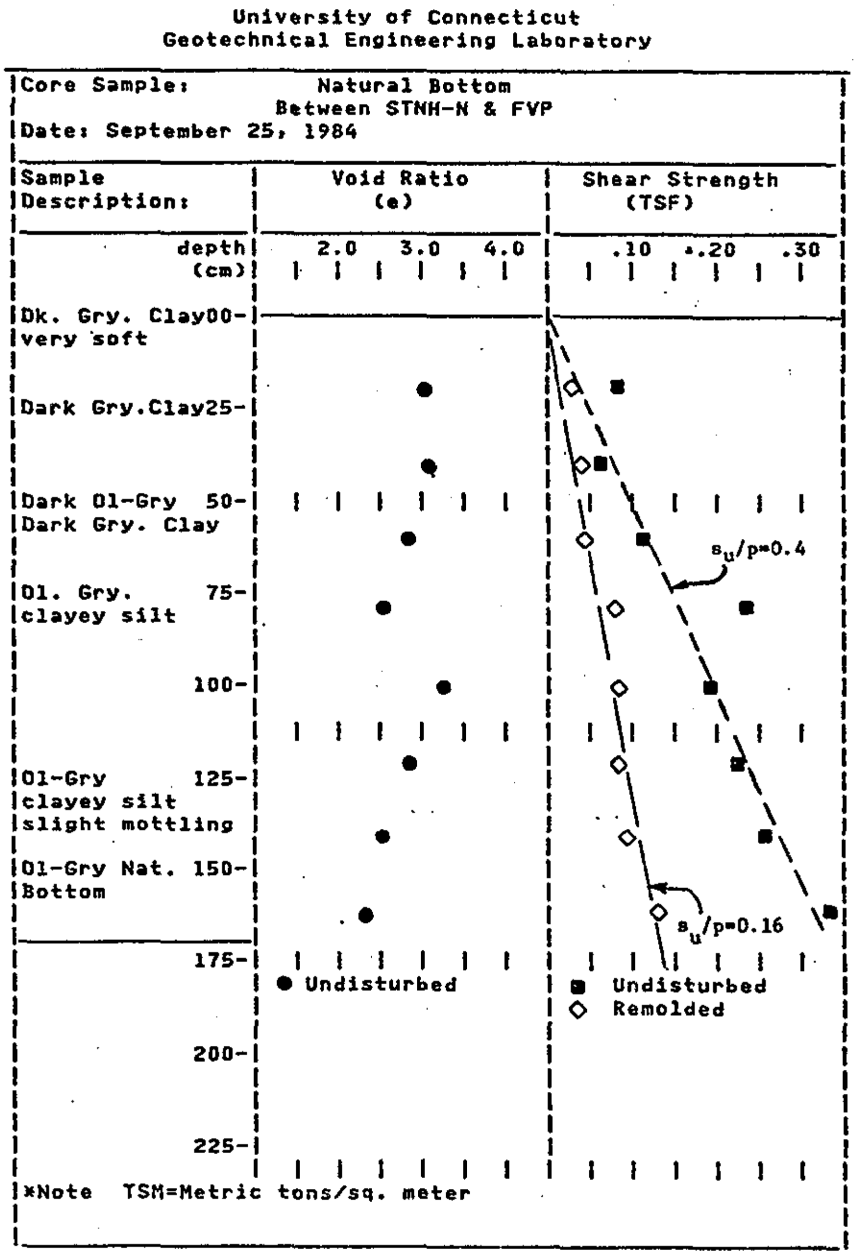

FIGURE V-4-1 Sediment core sample from natural bottom

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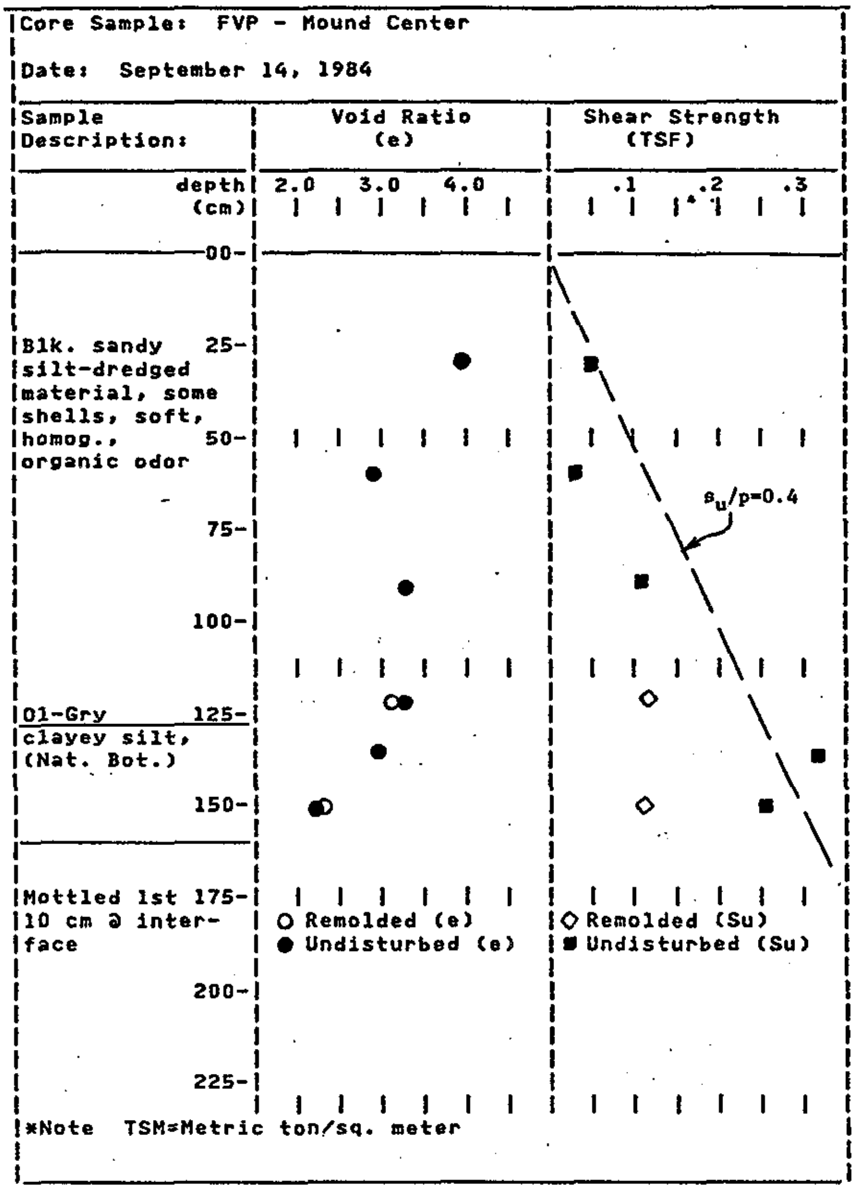

FIGURE V-4-2 Sediment core sample from center FVP mound.

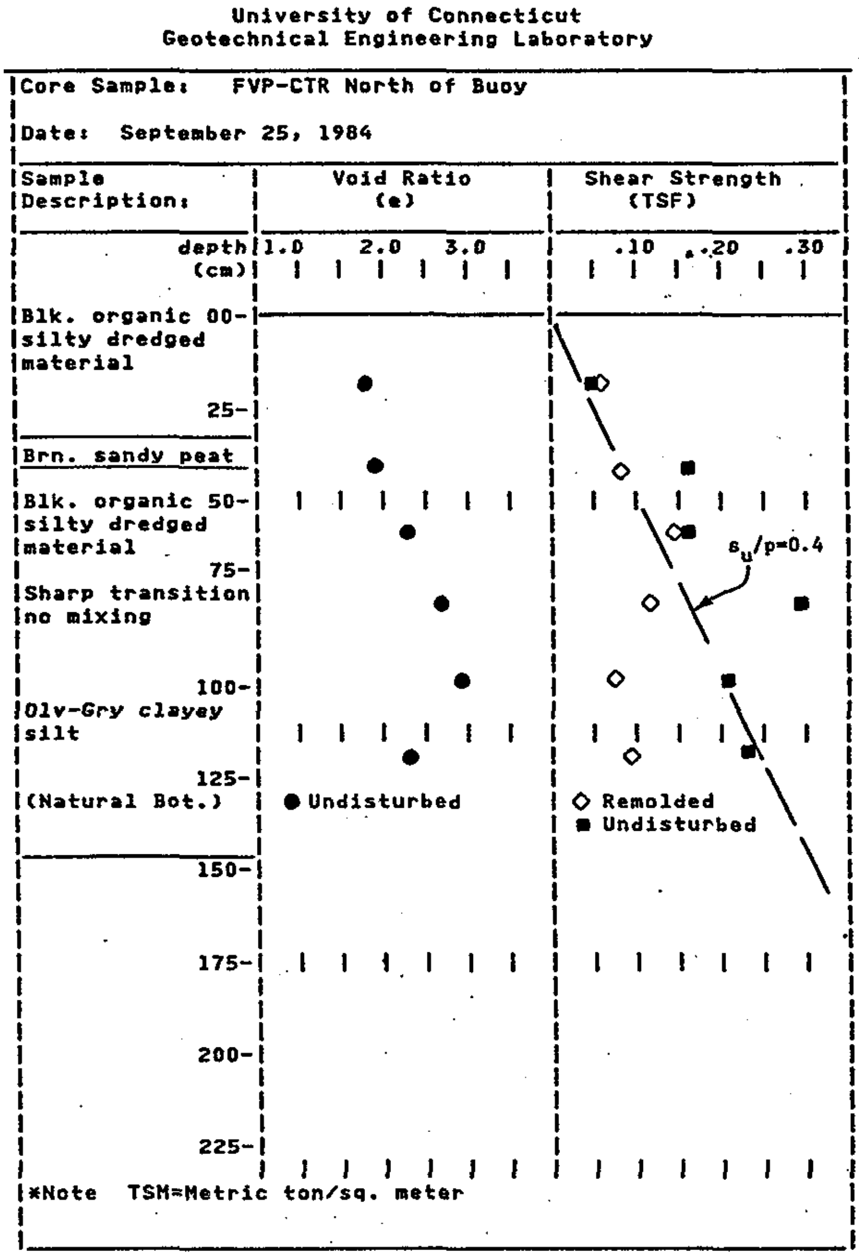

FIGURE V-4-3. Sediment core sample from FVP-CTR.

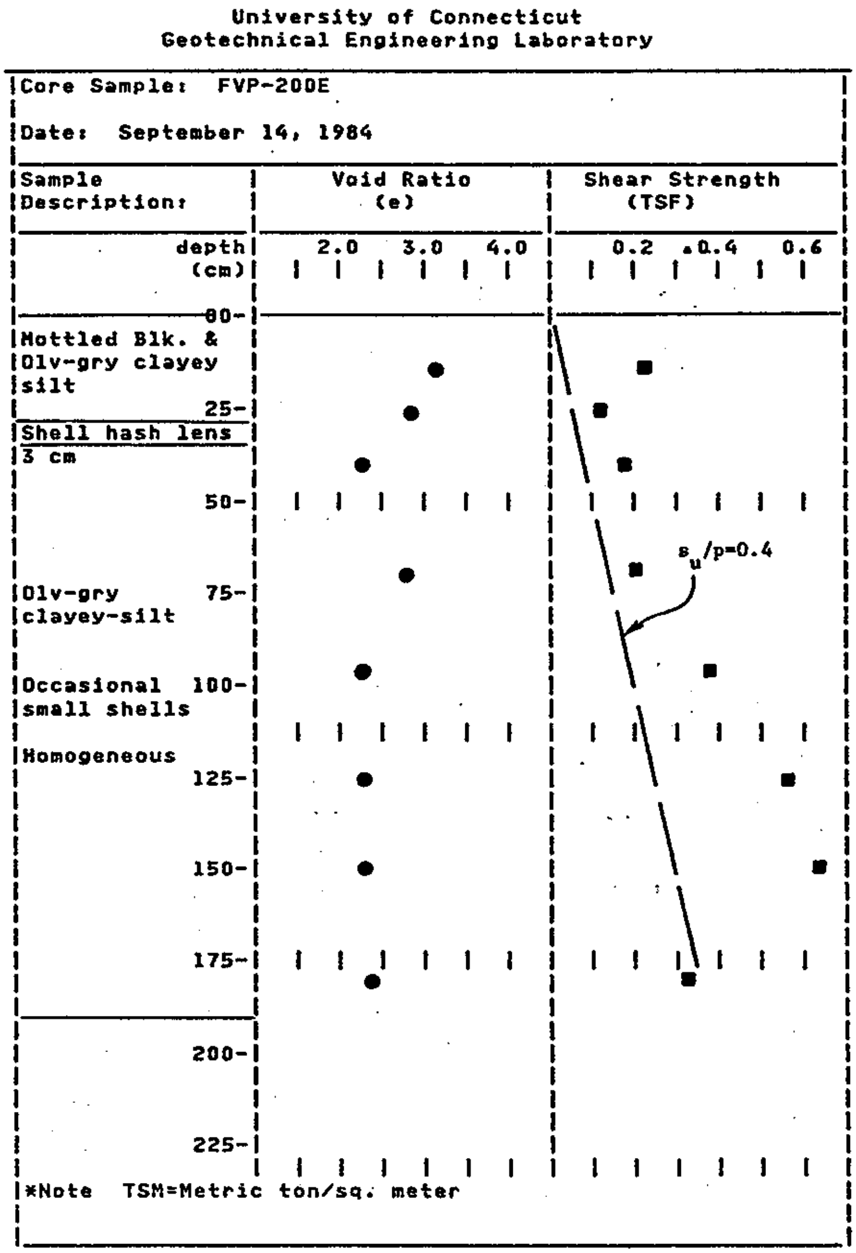

FIGURE V-4-4 Sediment core sample from FVP-200E.

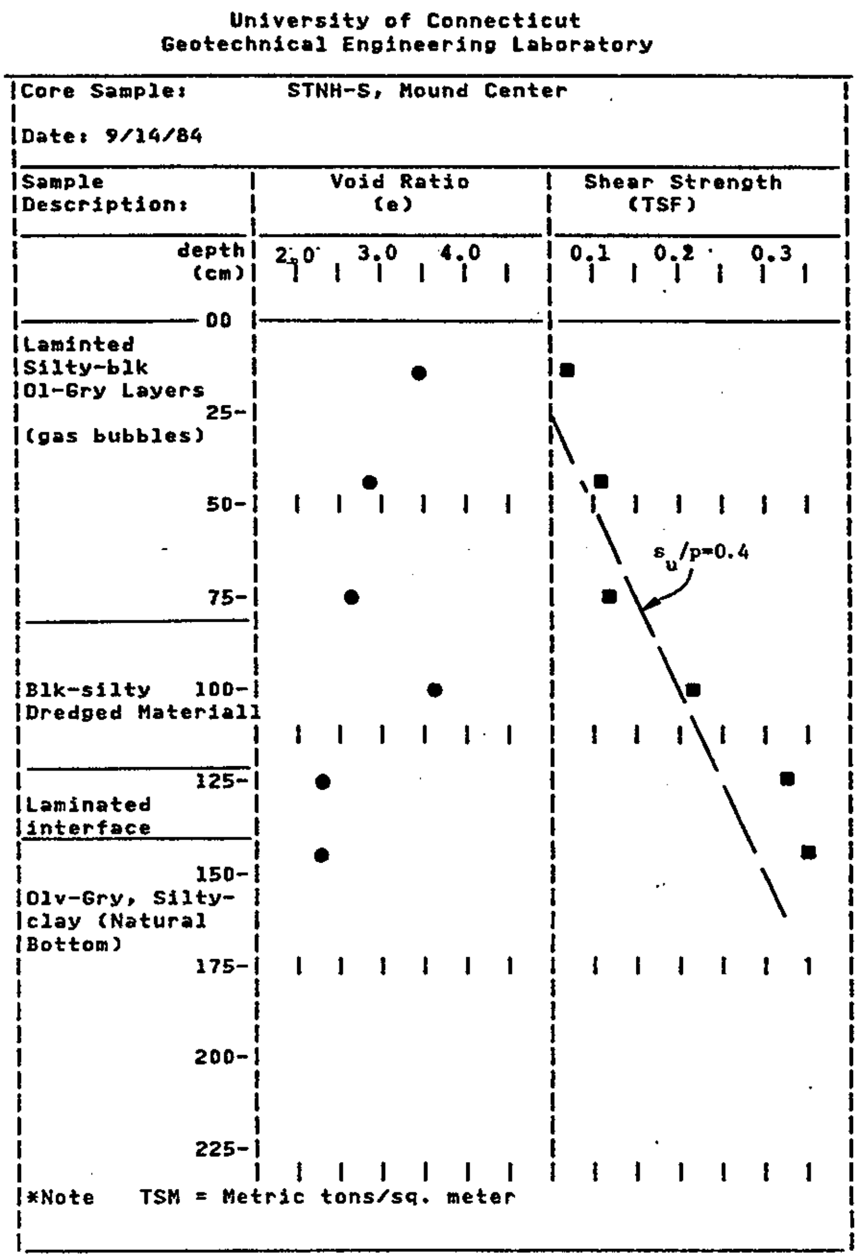

FIGURE V-4-5 Sediment core sample from center of STNH-N mound.

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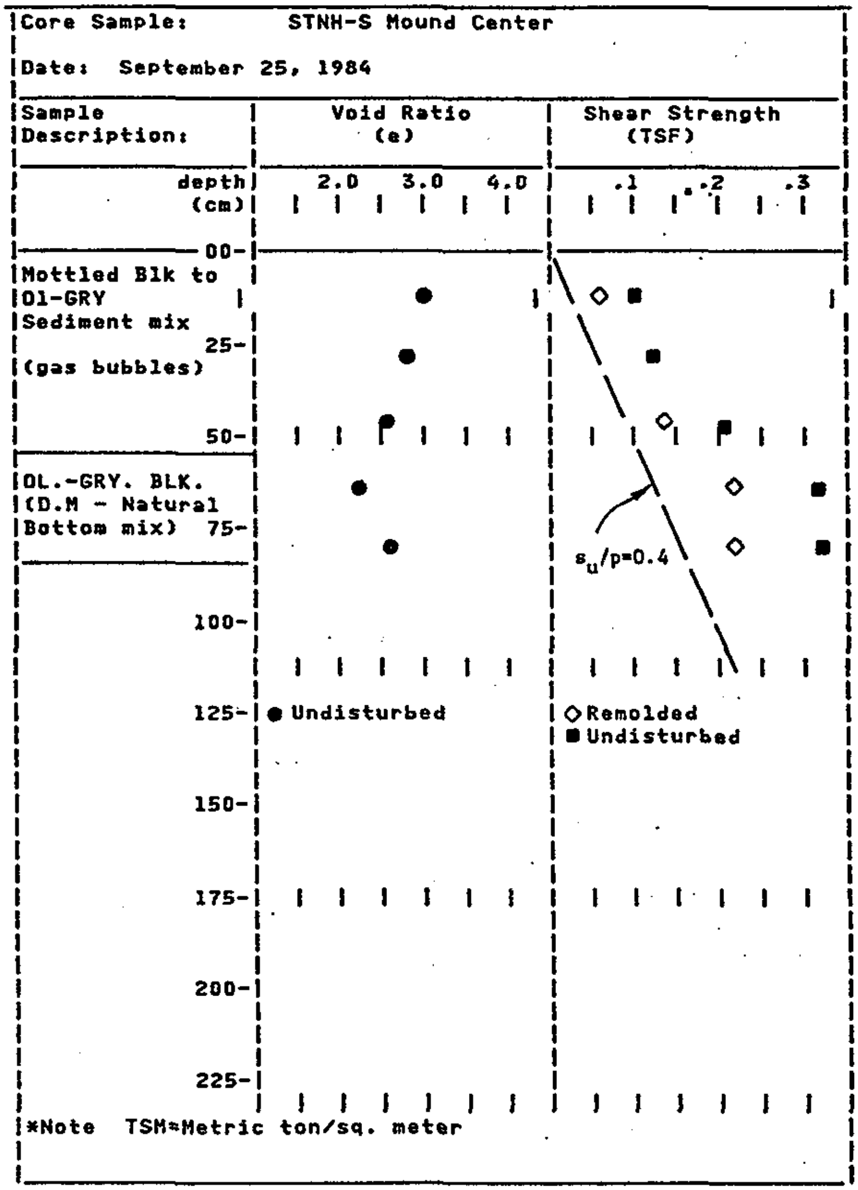

FIGURE V-4-6 Sediment core sample from center of STNH-S mound.

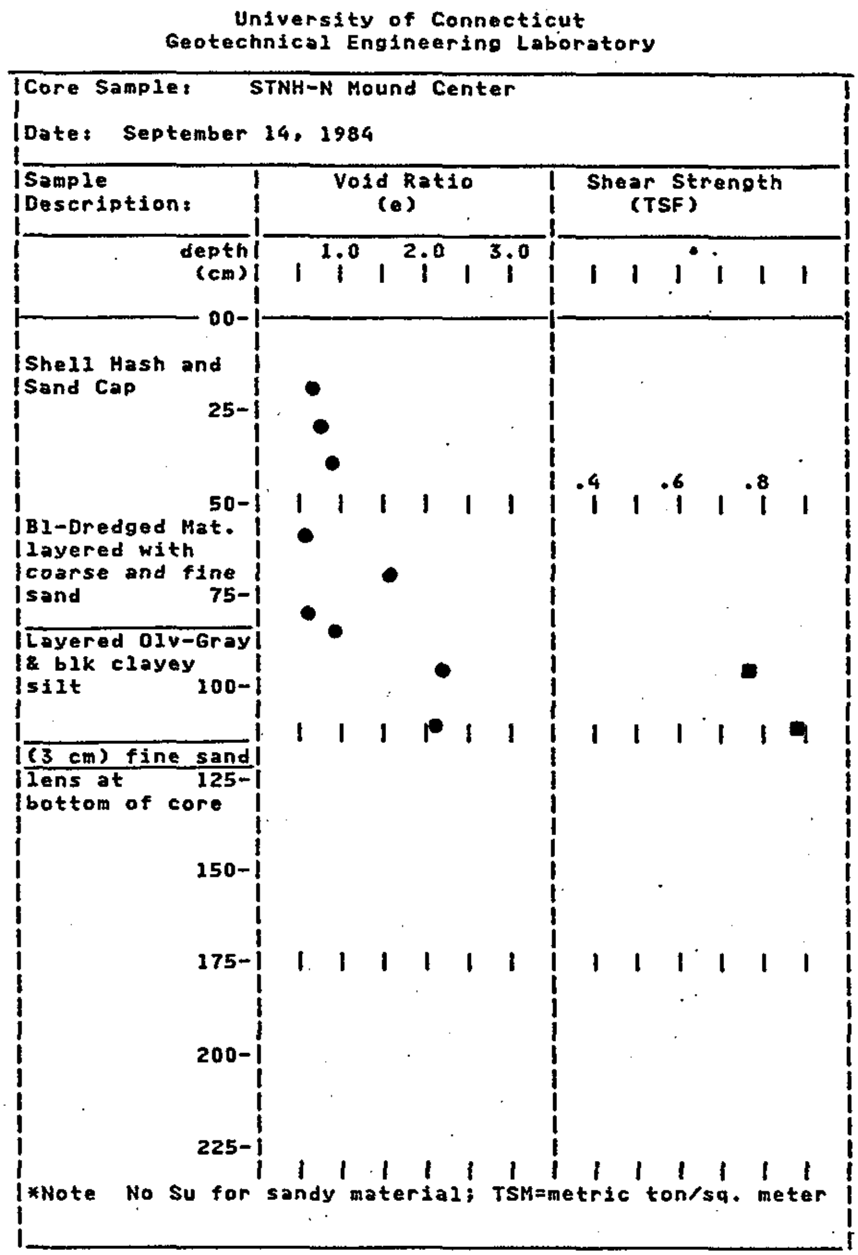

FIGURE V-4-7 Sediment core sample from center of STNH-N mound.

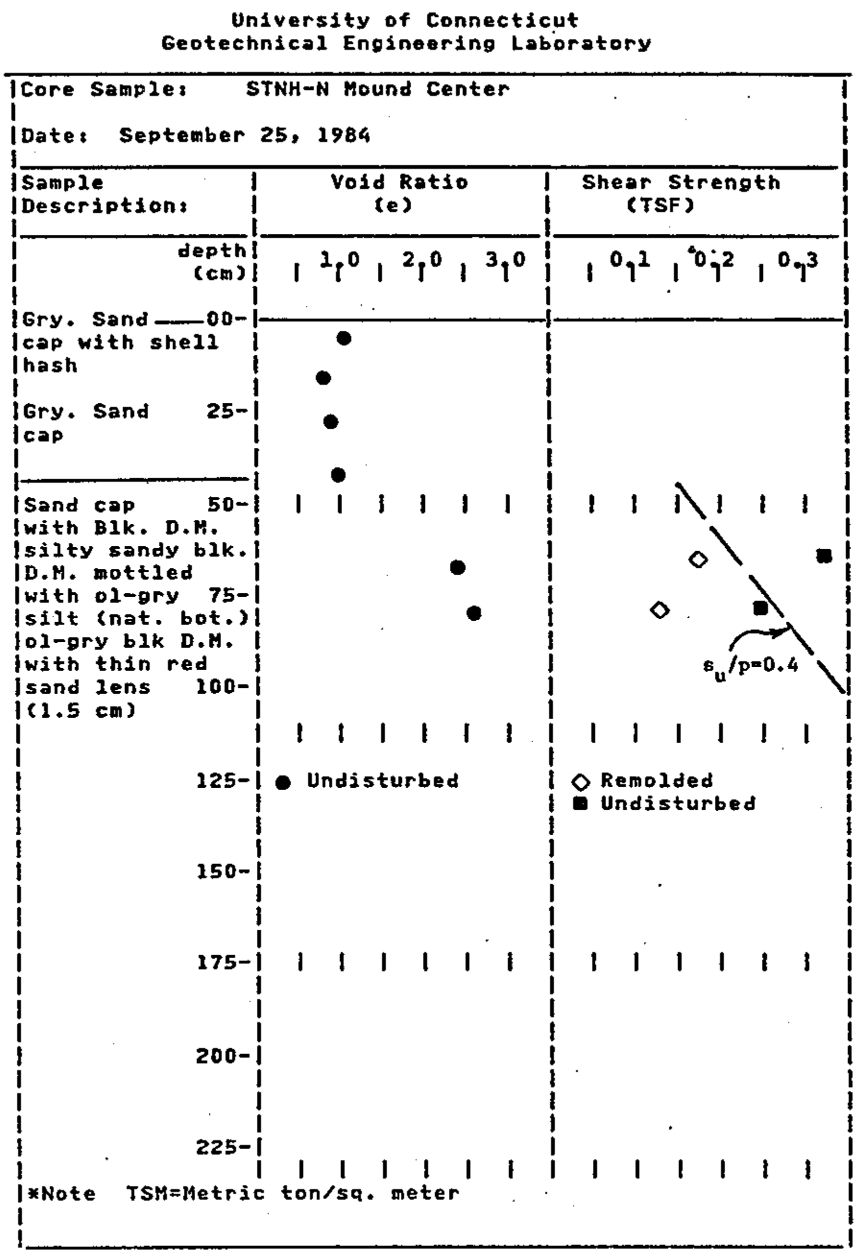

FIGURE V-4-8 Sediment core sample from center of STNH-S mound.

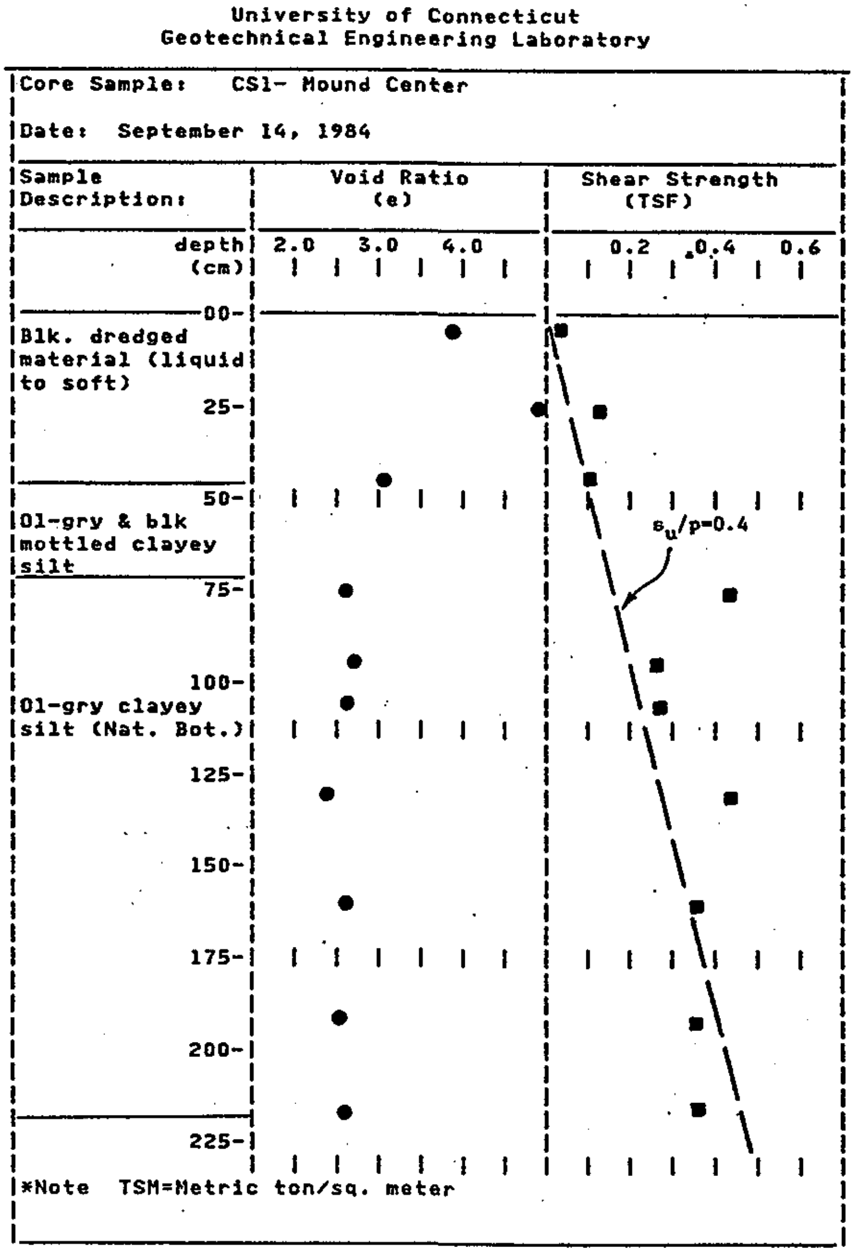

FIGURE V-4-9 Sediment core sample from center of CS-1 mound.

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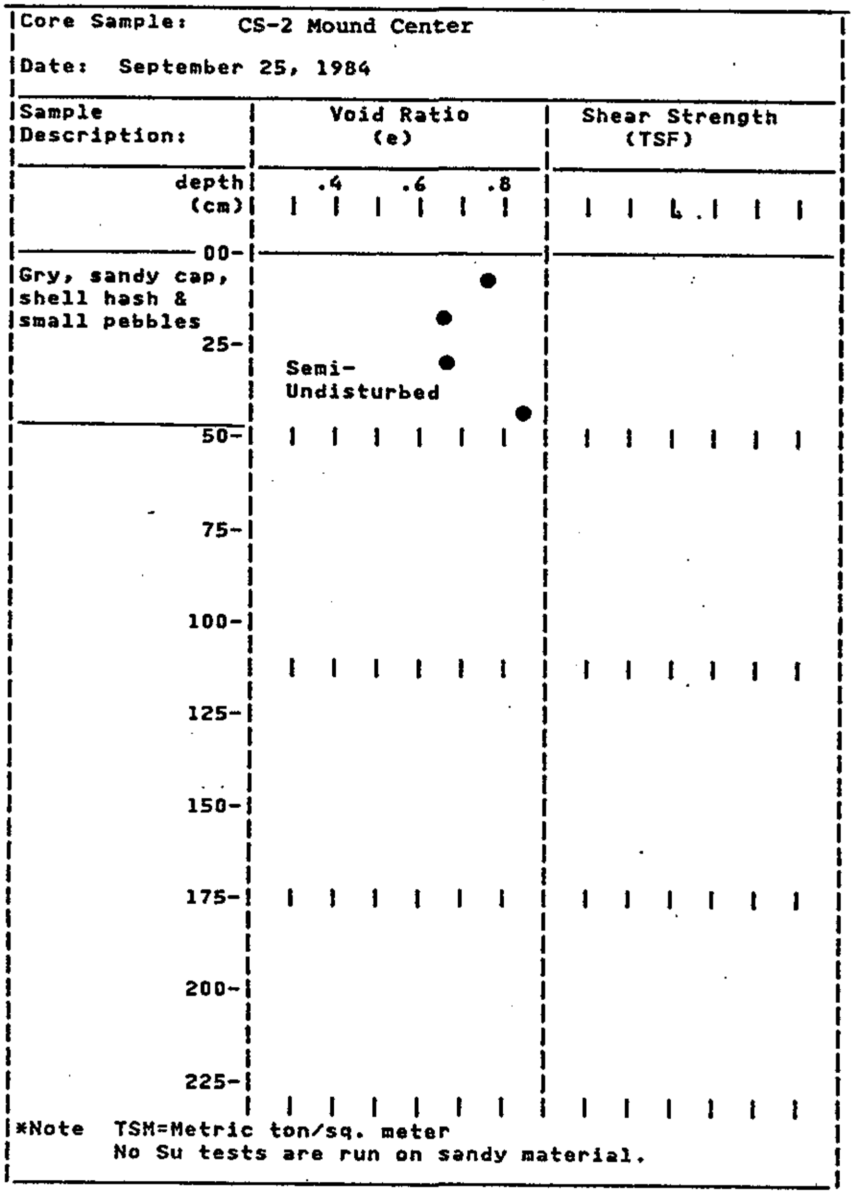

FIGURE V-4-10 Sediment core sample from center of CS-2 mound.

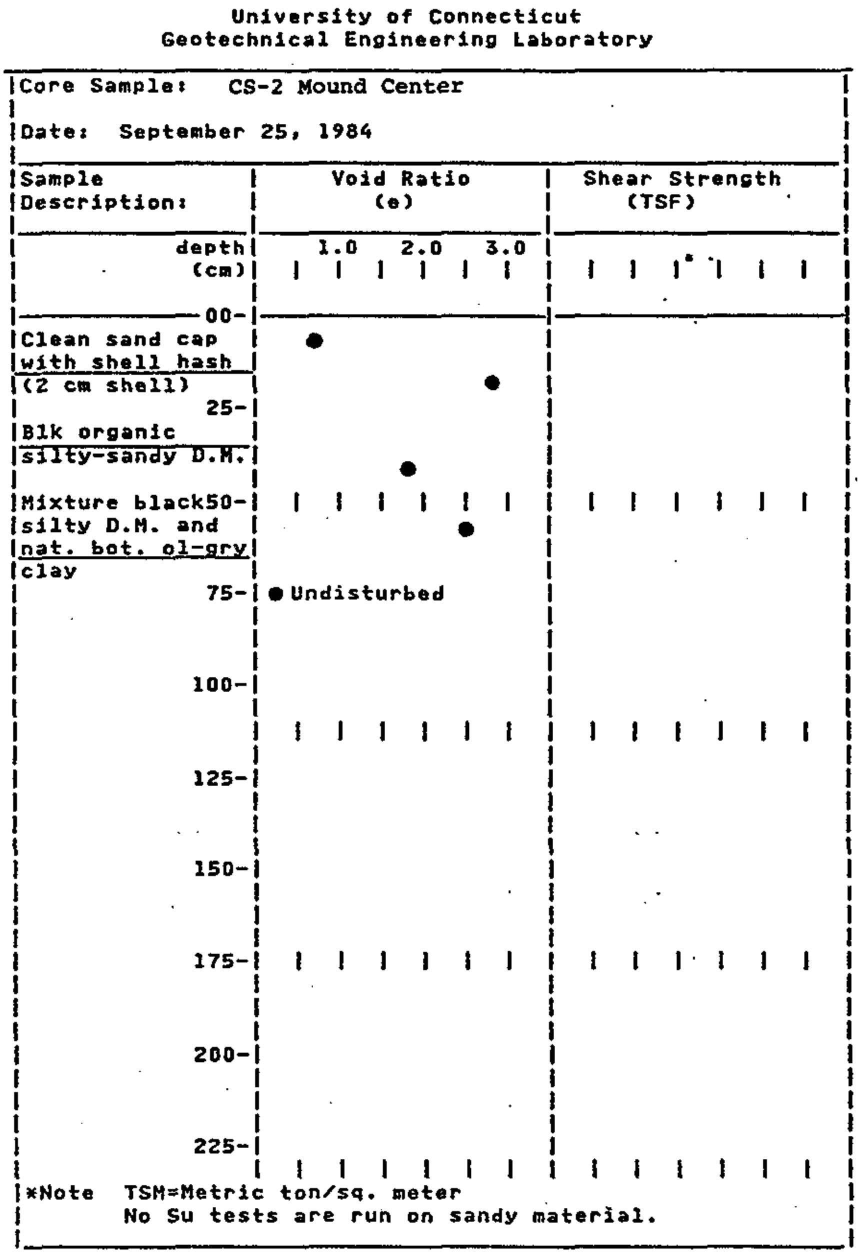

FIGURE V-4-11 Sediment core sample from center of CS-2 mound.

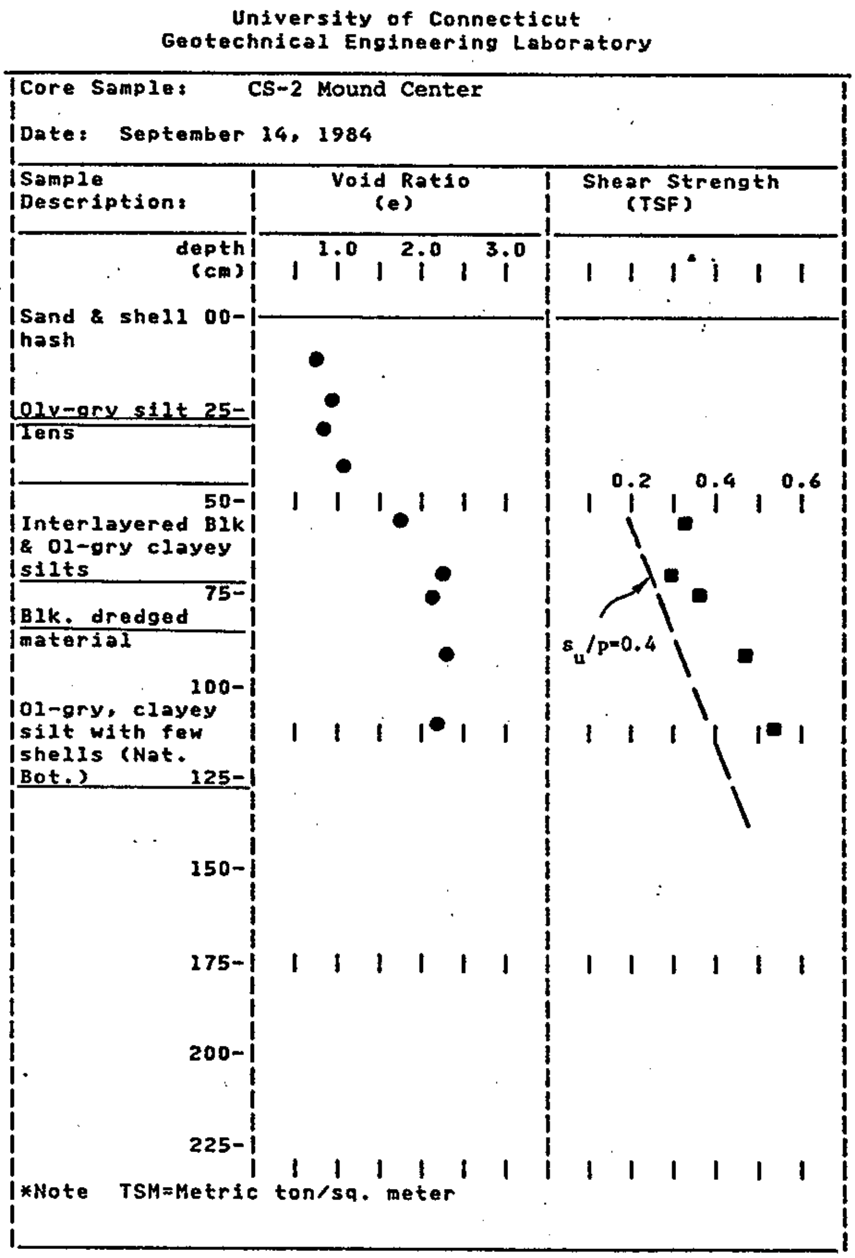

FIGURE V-4-12 Sediment core sample from center of CS-2 mound.

and Gs=specific gravity which is 2.72 for typical sediment at the CLIS site. Using void ratio and specific gravity, it is possible to estimate the weight of solids per unit volume or dry unit weight

$$\gamma_D = \frac{Gs\ \gamma_w}{1 + e}$$

where γ_w = unit weight of water (1 g/ml).

The natural bottom core is presented in Figure IV-4-1 as a reference for comparison. Figures IV-4-2 through 12 show the results from the disposal mounds.

4.1 Natural Bottom

One core of the natural bottom sediment was taken about half-way between the STNH-N and FVP mounds (Fig. V-2-1). Core samples from the CLIS site during the last year have shown that natural bottom is a normally consolidated clayey-silt of recent geologic age. While this core is typical of others, it tends to be dark gray in color to a depth of about 1 m compared to the usual olive gray color. The texture of this entire core is very uniform from top to bottom with no sign of stratification. There were also no small shells in this core as have been observed in other core samples. The physical properties of the natural bottom sediments are about as expected (Fig V-4-1). The void ratios tend to diminish slightly from top to bottom showing a range of 2.3 to 3.3 with an average of about 2.6. Undrained shear strengths are typical of a normally consolidated deposit and have a zero strength at the sediment-water interface and increase linearly with depth. Triaxial compression tests for natural bottom sediments have previously shown that the ratio of undrained shear strength to effective overburden pressure (Su/p) is 0.4. Using a void ratio of 2.6 to estimate buoyant unit weight and thus, overburden pressure, the relationship for Su/p=0.4 has been placed in Figure IV-4-1 and shows excellent agreement with shipboard measurements of undrained strengths for the undisturbed samples. By reversing this process, a line of best fit has been passed through the shear strength data for remolding samples and yields Su/p=0.16. These strength profiles therefore show that the sensitivity of natural bottom sediments is about 2.5 compared to previous laboratory measurements of about 3.0.

4.2 FVP Mound

Core data from the uncapped FVP mound are shown in Figures V-4-2, 3 and 4 and there is a considerable variation in results. The property variations within the mound may perhaps be explained by the chunk-like, yet soft, nature of the dredged material and heterogeneous grain size of the deposited mass. Void ratios tend to decrease with depth in some cores (Figs. V-4-2 and 3) and increase with depth in others (Fig. V-4-5). Natural bottom sediments exhibit the usual void ratios of about 2.5. Undrained strength results for the mound are scattered about the line representing Su/p=0.4 where as the natural bottom strengths, once again, agree favorably with this relationship (except for core FVP-200E). At the perimeter of the mound (200E), the undrained strengths of the mound and underlying sediment show a more rapid increase of strength with depth. There is no obvious reason for this higher strength profile. The void ratios in the dredged material vary from 3.5 at the surface to 2.5 at the bottom of the sample corresponding to dry unit weights of 0.60 and 0.78 g/ml, respectively, or an increase of 30%. Therefore, during a mass balance analysis of dredged material, density variations may be significant with both time and depth in mound.

4.3 Stamford/New Haven South Mound

The STNH-S mound is capped with a clean layer of soft silt and is expected to exhibit normally consolidated behavior. Since the silt cap has a black to dark gray color, it is difficult to visually distinguish the cap from the dredged material at the mound as center shown in Figures V-4-5 and 6. However, the surface layer in each core was gas charged and this is probably the cap layer. In both cores there is the expected reduction in void ratio and corresponding increase in undrained shear strength. The undrained strength profile in Figure V-4-5 agrees favorably with the relationship of Su/p=0.4. Both the undisturbed and remolded strengths in Figure V-4-6 are greater than expected and these anomalously high strengths are probably due to a malfunction of the gravity corer whereby the complete sediment profile was not sampled.

4.4 Stamford/New Haven North Mound

Two cores from the center of the sand-capped STNH-N mound (Figs. V-4-7 and 8) show that the sand cap has a void ratio that varies from about 0.6 to 1.0 with an average of 0.8. In both cases the cored thickness of the sand cap is significantly less than the 2 m average for this mound and the strength of cohesive sediment beneath the sand cap is greater than expected for a normally consolidated deposit with Su/p=0.4. Both factors are probably a result of incomplete or discontinuous sampling of the sediment profile. During core sampling the sand cap flows into the coring tube until wall friction exceeds the bearing resistance at the corer tip. At this point the corer penetrates the seabed without sampling until a point where the sediment strength is sufficient to overcome internal wall friction. From the strength data in Figure V-4-7, it appears that as much as 3 m of sediment below the sand cap maybe missing, whereas, the data in Figure IV-4-8 show that little or no sediment is missing. From the limited data in Figure IV-4-8 (and later in Fig. V-4-12) it appears that the sand cap, with its greater density than the silt cap, appears to cause more consolidation and strengthening of the capped dredged material.

4.5 Cap Sites #1 and #2

One core (Fig. V-4-9) was obtained from the center of the CS-1 mound, while three cores (Figs. V-4-10, 11 and 12) were obtained from CS-2.

The core from the center of CS-1 mound was similar to those obtained earlier at this site and did not contain any evidence of a sand cap. The void ratio and undrained strength profiles for this core are typical of normally consolidated natural bottom and uncapped mound profiles shown in Figures V-4-1 and 2.

Two of the cores from CS-2 (Figs. V-4-10 and 11) have low recoveries of only about 0.5 m which can be attributed to the difficulty of gravity coring through the sand cap. The core descibed in Figure V-4-10 was all sand whereas the core shown in Figure V-4-11 showed the three basic layers that comprise the mound - the cap, dredged material and natural bottom clayey silt. No strength mesurements were made on these predominantly granular sediments.

The third core from the center of mound CS-2 (Fig. V-4-12) contained all of the sediment layers from cap through natural bottom; however, the capped dredged material layer was only about 15 cm thick and was overlain by 25 cm of intermixed dredged material and natural bottom sediment. Again the coring procedure probably undersampled the thickness of the capped dredged material since it does not have the strength to overcome wall friction. The undrained strength profile is slightly greater than the typical Su/p=0.4, but its greater value tends to be a reflection of the dense sand cap rather than the poor core sample.

5.0 SUMMARY

Twelve gravity core samples were taken from the dredged material disposal area in Central Long Island. Samples from these cores were tested for water content and fall cone penetration resistance. From these results void ratios and shear strengths were estimated. The geotechnical properties of the natural bottom, dredged material and capping material were investigated separately. The natural bottom material indicated a ratio of undrained strength to consolidated pressure (Su/p) equal to 0.4 which agrees with laboratory results. Uncapped and silt capped mounds also have an average Su/p ratio of about 0.4 although there is substantial scatter in strength data for the deposited sediment which may reflect its heterogeneous nature. Some of the samples from the sand capped areas indicated that the material in the core sampler was taken from deeper in the mound than indicated by its relative position in the sampler. Also, the limited strength data for the sand capped dredged material shows a greater strength profile than for silt-capped or uncapped mounds probably due to the greater density and permeability of the sand cap.

VI. SUBMERSIBLE AND ROV SURVEYS AT DEEP WATER DISPOSAL SITES IN NEW ENGLAND

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VI. SUBMERSIBLE AND ROV SURVEYS AT DEEP WATER DISPOSAL SITES IN NEW ENGLAND

1.0 INTRODUCTION

Investigations of biological and substrate conditions at three New England dredged material disposal sites were conducted during July 1984 utilizing the Remotely Operated Vehicle (ROV) "Recon IV" and the submersible "Mermaid II". Deep (30-100 m) coastal sites within the Gulf of Maine and Massachusetts Bay were surveyed to determine: sediment micro-scale topography, peripheral limits of dredged material mounds, faunal recolonization patterns, and predominant macrofauna associated with mound features and the near field vicinity. Linear ROV photodocumentation (video/35 mm) transects provided quantified data on benthic habitat existing at proposed disposal locations and at active disposal sites, abundance and distribution of motile epibenthic species, and important behavioral observations on commercial fishery resources. Advantages of systematic inspection of biological/physical impact zones using an ROV include quantified field of view, close-focus resolution, low species avoidance effects, extended observation time, and precise surface navigation control. Results obtained from ROV reconnaissance were accurately charted by a Del Norte/Honeywell/Computer track/plot interface system provided by SAIC.

The NOAA National Undersea Research Program at the University of Connecticut chartered the ROV/Submersible/Ship system from International Underwater Contractors, New York for ecological in-situ studies off the northeast coast Leg one (6 days) was devoted to support of the New England Division-Army Corps of Engineers (NED-COE) dredged material management program (DAMOS), coordinated through SAIC. This investigation represents the first extensive combined ROV/submersible application to monitor northeast dredged material disposal sites and presents information useful for site selection, fishery impact evaluation and region-wide management procedures for deep water disposal sites.

Detailed photographic and video analysis has been conducted to quantify the observations for the three sites. A chronological descriptive log for both Recon IV and Mermaid II video and still photographic series were assembled and include accounts of changing sediment patterns, cluster aggregation of epibenthic species, bioturbation behavior, and unique zones of sessile organisms

2.0 BACKGROUND

During the last 40 years, the demand for channel dredging to maintain and develop navigable waterways has necessitated designation of ocean disposal sites to accomodate dredged material. During the 1970's, environmental impact and ocean disposal laws reduced the number of approved and permitted sites. Several New England states were charged with establishing criteria for dredged material (toxic and heavy metal, PCB, hydrocarbon content) and redesignating fewer, carefully selected sites.

In the New England region, monitoring the impact of dredged material disposal has been undertaken by the New England Division of the U.S. Army Corps of Engineers. As a result, the DAMOS program, a multi-disciplinary study was organized, which addressed the physical, chemical and biological parameters affecting the containment, disposal and management of dredged material (Shonting and Morton, 1982). This program includes research on aspects of dredged material stability, bathymetry of the dredged material mounds, suspended sediment transport, surficial sediment chemistry, pollutant bioaccumulation by mussels, benthic assemblage biology and visual surveys by divers and remotely operated vehicles (see Morton and Karp, 1980 for examples).

DAMOS studies have indicated that changes in topographic relief attract greater numbers of megabenthic species when compared to the flat featureless bottom adjacent to disposal grounds (Stewart 1982). These are of major concern, since a number of commercially and recreationally important molluscan, crustacean and finfish species are attracted to disposal site areas (DAMOS, 1979a; Pratt, 1970a). Localized fishing and pollutant assimilation in these organisms is a concern to all coastal states and consumers.

Concern for changes in pollution load and biotic assemblage effects has created a need to find alternatives to normal ocean disposal operations. Simple timing of dredge disposal operations to minimize effects of recruitment to infaunal populations has been investigated (Rhoads, et al., 1978). Capping procedures to cover contaminated material with cleaner sediments have been demonstrated to be logistically and econonmically feasible (Morton, 1980). Also, existing requirements of point-accuracy disposal attempt to reduce bottom area impacted due to burial and contribute to planned sequential dredged material mound creation.

Understanding aspects of dredged material behavior, bioturbation, sediment transport and biotic-sediment interaction are essential for the proper planning and management of ocean disposal site selection and management. In-situ studies utilizing SCUBA diving and remote photographic technology have been an important part of the long-term monitoring program at ocean disposal sites in this region (Stewart, 1980; Stewart, 1982). These studies have allowed investigators to identify:

baseline habitat characteristics and megabenthic species composition before disposal operations as part of the site selection process; dredged material, recolonization trends, faunal interactions with dredged material and operations assessment during active disposal operations; and megabenthic recolonization, succession, sediment feature erosion and disposal mound boundary stability over the long-term after disposal operations have terminated. Determination of these key factors is not possible using surface oriented sampling methodologies.

The three sites considered for study under this program were the Foul Area in Massachusetts Bay, Portland, Maine and a new site for designation at Cape Arundel. The Foul Area disposal site (42°25.5'N, 70°34.7W, approx. 90 m depth) is located 12 nm east of Boston Harbor and is delineated by a 2 nm radius about a central disposal buoy (Fig. VI-2-1). Past disposal operations included indiscriminate release of various industrial and maintenance materials throughout the general designated area. To conform to more precise dredged material management and to test operational abilities of point accuracy disposal, two areas within the Boston site were selected for point disposal by scow and hopper barge methods, respectively. Bottom type consists of soft fine grained mud-silt with low relief.

The Cape Arundel historical disposal site (43°17.5'N, 70°27.1'W, approx. 40 m depth) is located approximately 2.75 nm south of Cape Arundel (Fig. VI-2-2b). Since the site supports fishing activities, a new site is under consideration which will have less potential impact. A new site (43°18.0N, 70°27.1'W, approx. 44 m depth) to the north of the historical site is being investigated for site designation to determine the feasibility of this area containing the dredged material and being more suitable for ecological and monitoring purposes (Fig. VI-2-2a).

The Portland disposal site (43°34.0'N, 70°02.0'W, approx. 60 m depth) is located 8 nm east southeast of the Portland Harbor entrance and covers a 1 nm^2 area (Fig. VI-2-3). The area was recently designated as an offshore site to accommodate maintenance and expansion of the Portland port. All disposal has been exclusively dredged material. Point-disposal target buoys and bathymetric monitoring have been conducted as part of the DAMOS management procedure.

The long-term monitoring of both the Foul Area disposal site and the Portland disposal site in the Gulf of Maine have been part of the DAMOS program for several years. The physical and biological characteristics of both these sites are given in DAMOS reports (1979 a,b,c). The Portland site is discussed further in Morton and Karp (1980). Point dumping has not always been used at the Foul Area site and dredged material, wrecks, munition, etc. are spread over a wide area. A recent NOAA/EPA study was directed at search and location of low level radioactive waste canisters disposed during the 1950's. The designated Portland site has been subjected to point dumping disposal operations since its inception. Reactivation of a disposal site off Cape Arundel, Maine is now being considered and

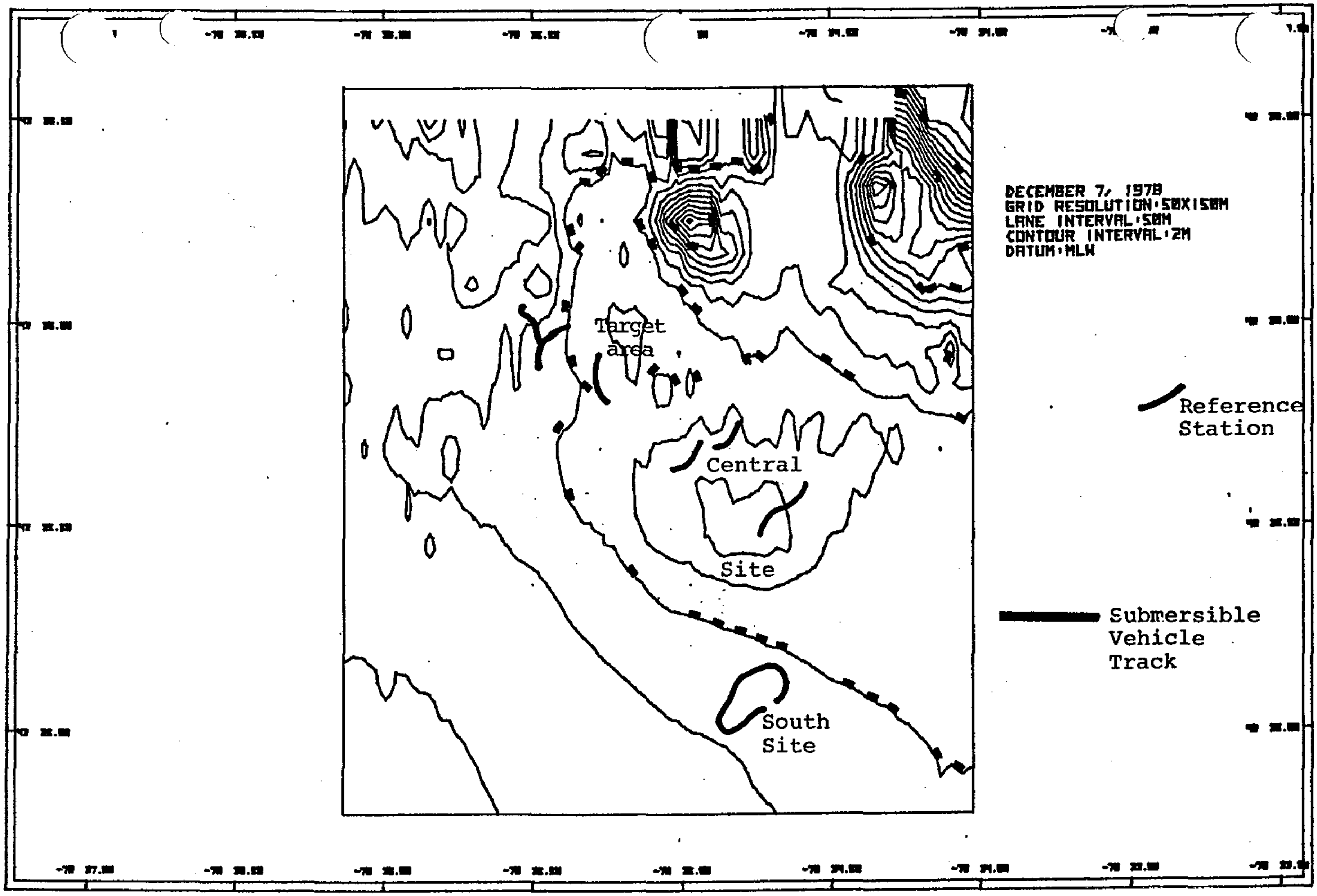


FIGURE VI-2-1. Foul Area Survey Site

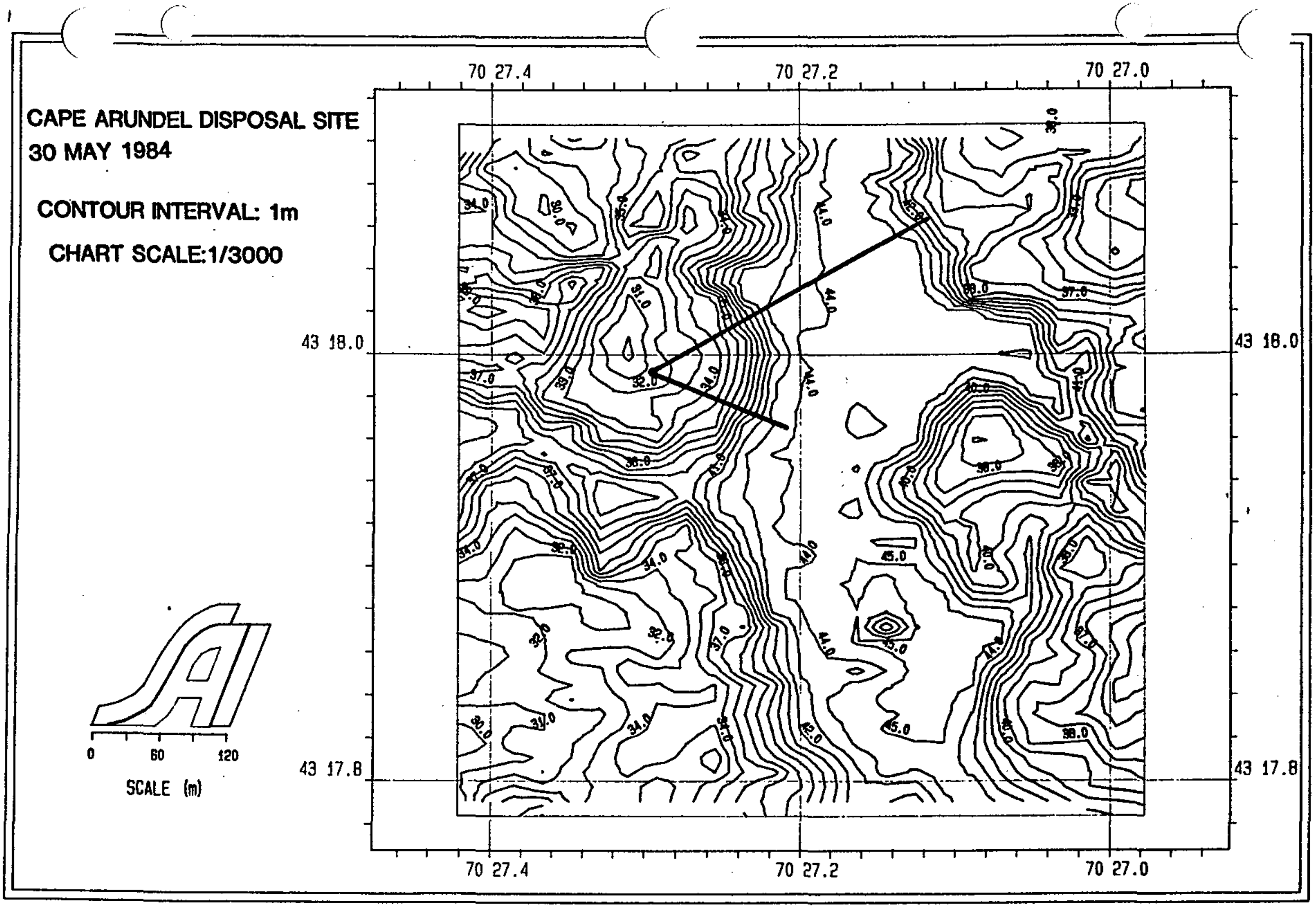


FIGURE VI-2-2a. Cape Arundel Survey Area

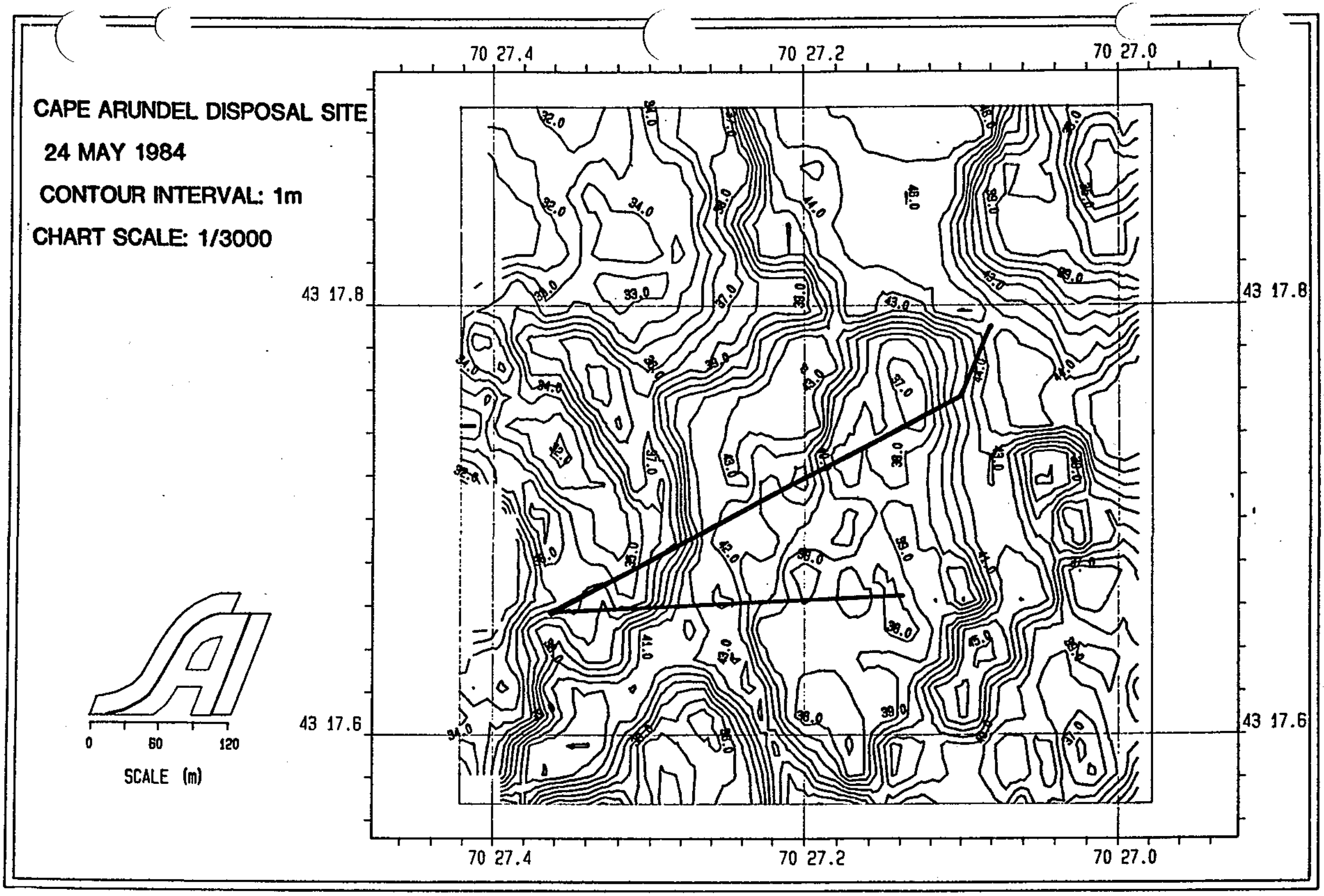


FIGURE VI -2-2b . Cape Arundel Survey Area

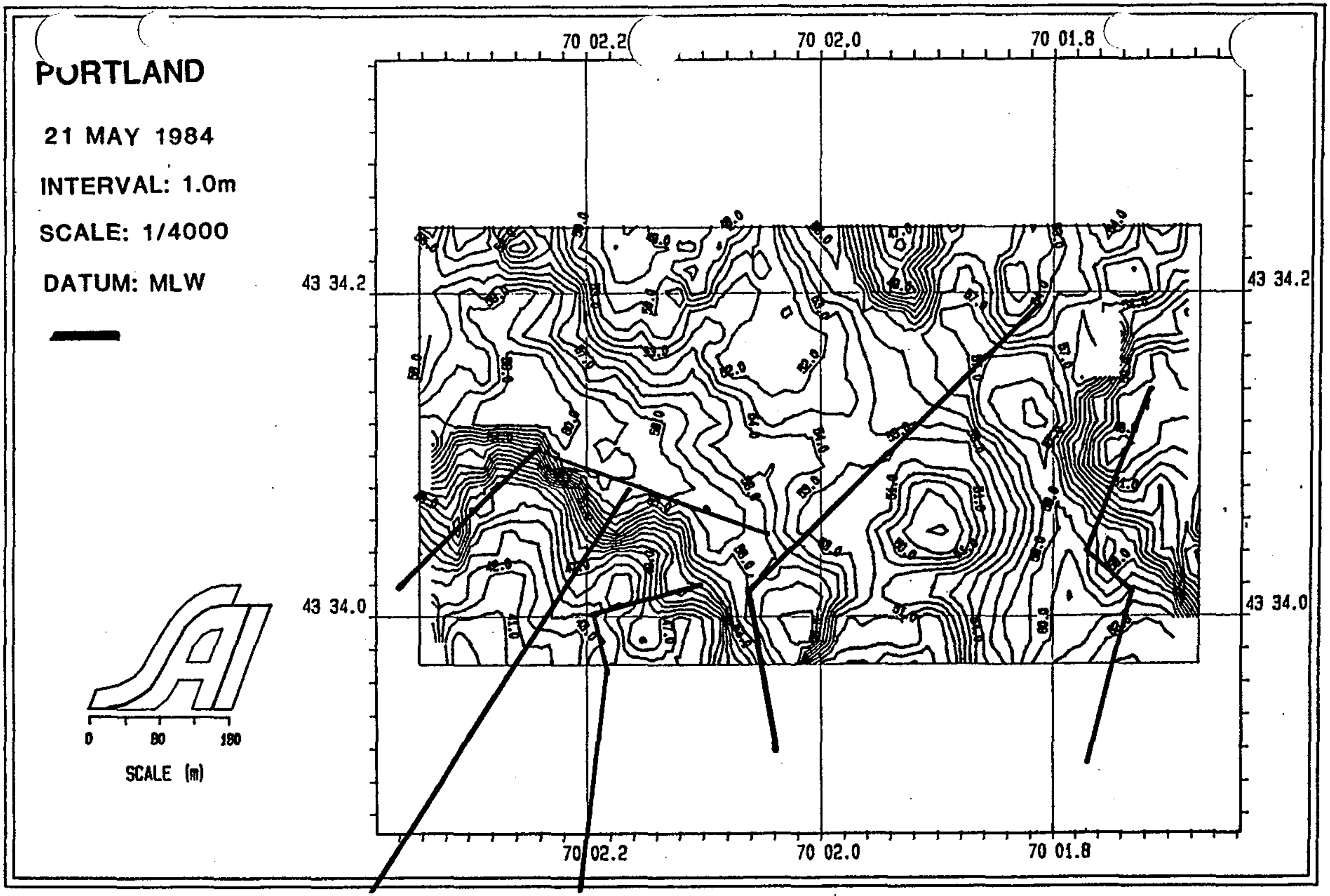


FIGURE VI-2-3. Portland Survey Area.

surveys have begun under the DAMOS program to assess the characteristics of two alternative locations.

Due to the water depths (>30 m) at these three disposal sites, no extensive in-situ observations of sediment conditions or megabenthic faunal surveys have been conducted. Limited remote 35 mm camera and video sled surveys have been conducted at the Foul Area and Portland sites (Stewart, 1980; SAIC, unpublished data). Photographic surveys and sampling to characterize the megabenthic assemblage at two shoaler areas adjacent to the Portland site were conducted using SCUBA in 1979 (Stewart, 1980), but direct observational assessment of the deep water dredged material mounds has not been accomplished due to the lack of undersea capabilities within the program. The value of visual inspection has been apparent on the shallow southern New England sites. Since disposal operations at these deeper sites are anticipated to continue into the future, monitoring is essential for managing these areas properly. The expanded use of deep ocean technology (manned submersibles, ROV's) allows scientists to monitor the in-situ conditions on a real-time basis.

This report summarizes the operational aspects and findings of surveys conducted at the Foul Area, Cape Arundel and Portland disposal sites (Figures VI-2-1, 2, 3) utilizing a manned submersible and ROV to extend monitoring efforts to these deep water sites. Methodologies already developed and tested at shallow water sites by SCUBA divers for monitoring surveys within the established DAMOS program (Stewart, 1982) were used and adapted for submersible and ROV operations.

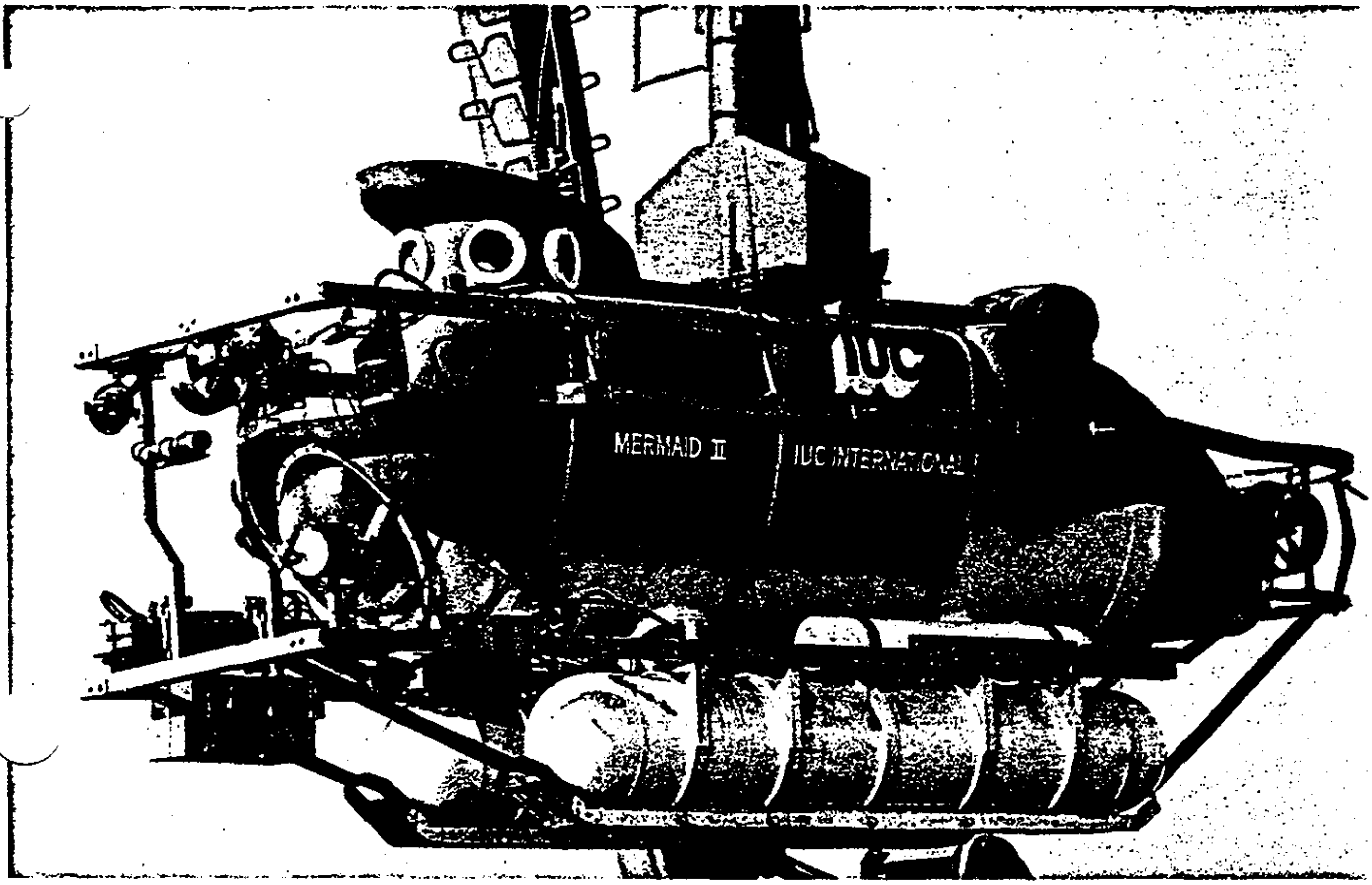
3.0 MATERIALS AND METHODS

Surveys were conducted utilizing the manned submersible Mermaid II and the ROV Recon IV (International Underwater Contractors Inc., N.Y.). Mermaid II (Figure VI-3-1, Table VI-3-1) is a two person (one pilot, one scientist) vehicle with 1000 foot (305 meter) operating depth. A hemispherical dome at the bow is directed below the hoizontal which allows convenient viewing of the substrate. Recon IV (Figure VI-3-2, Table VI-3-2) is a ROV vehicle with 2300 foot (701 meter) operating depth. This vehicle, like the manned submersible, can be flown over or propelled as a sled on bottom while conducting surveys.

Both systems utilize a Subsea CM 150 color video camera system (with 1/2 inch VHS recording and audio annotation capabilities) on a pan/tilt head. Still photographs were taken with a Photosea camera and strobe system (250 exposure capability). The still photography system was on the pan/tilt head of the Mermaid II and was on a fixed mount on Recon IV. Table VI-3-3 summarizes camera system characteristics.

In order to determine standard viewing dimensions for the 35 mm still and pan/tilt video cameras on the ROV, a

Mermaid II:
1,000-Foot Submersible



The Mermaid II is a manned submersible capable of carrying out a broad range of undersea tasks in water depths to 1,000 feet. For example, close-up inspections are performed easily in minimal visibility through the combined use of a 30-inch-diameter bow window, obstacle-avoidance sonar and closed-circuit television. A highly sophisticated bottom-mounted acoustic transponder navigation system permits Mermaid II to follow a preprogrammed route and exactly—to within three feet—relocate any given point without assistance from a surface vessel.

Mermaid II is the underwater component of a fully integrated offshore deep-diving system. The surface component of this system is IUC's 143-foot-long support vessel, Aloha, with its stabilizing bow thruster and specially designed launch-and-recovery system whose 30,000-pound capacity permits safe operation of Mermaid II over the stern in heavy weather. In addition to a full complement of navigation and communications equipment, the Aloha can be outfitted with a double lock decompression chamber diving bell and other equipment needed to support deep-diving operations.

The features of the highly versatile Mermaid II include:
- A two-man configuration.
- Excellent maneuverability, including hovering capability.
- 30-inch-diameter bow window giving diver-operator and observers an outstanding field of view.
- 1,000-pound payload.
- Capacity for wide range of navigation, observation and other mission equipment.
- Extensive life-support and backup systems.
- Versatile remote-controlled manipulator.

FIGURE VI-3-1 The "Mermaid II" Submersible

TABLE VI-3-1

Mermaid II: 1,000-Foot Submersible

Specifications:

General

Operating depth:	1,000 feet (305 meters)
Length o.a.:	20 feet (6.09 meters)
Breadth:	6.5 feet (1.98 meters)
Height:	9.4 feet (2.86 meters)
Tonnage (gross):	6.3 tons
Crew:	2
Life support:	240 man hours
Speed (cruising):	1.5 knots
Speed (top):	3 knots
Power:	28 kw
Propulsion:	7-hp fixed main thruster, 2 vertical and 2 lateral thrusters of 2 hp each
Maneuverability:	5 degrees and hovering, rotates 360 degrees at zero velocity
Payload:	1,000 pounds (454 kilograms)
Lift capability:	500 pounds (227 kilograms)
Certification:	American Bureau of Shipping

Work & Documentation

Viewports:	■ 8, including a 30-inch (0.76-meter) diameter bow window
Inspection equipment:	■ Pan-and-tilt CCTV and still cameras, plus audio and video recording
External lighting:	■ Two 350-watt and two 150-watt quartz iodide lamps
Manipulator:	■ One, with 5 degrees of freedom, 75 pounds (34 kilograms) fully extended

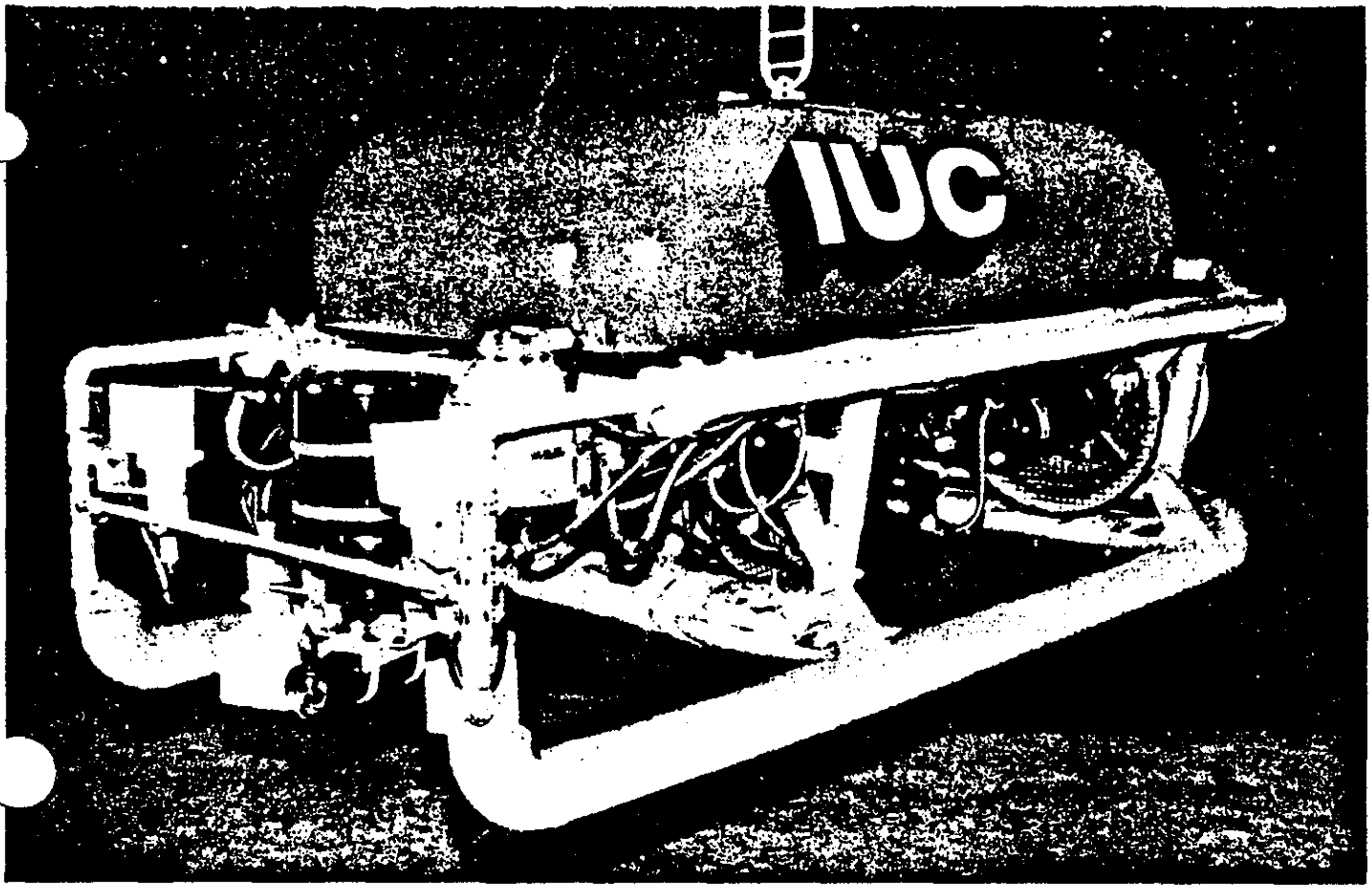
Navigation & Communications

Underwater:	Mesotech Acoustic 9 and 27 khz
Surface:	VHF-FM
Direction:	Sperry CL-II directional gyro
Altitude/depth:	Wesmar digital depth sounder
Obstacle avoidance:	Wesmar SS 140 Sonar
Tracking:	RS-7
Bottom/position:	ELA-20

Support Equipment

Equipment:	Battery charger and lift system

Recon IV:
2,300-Foot Remotely Operated Vehicle



IUC's Recon IV *is the first of a series of deep-water Recons* capable of work to 2,300 feet (701 meters). The Recon IV is a versatile, reliable vehicle, that has proven and demonstrated it's capabilities.

Recon can easily accept an assortment of bolt-on options to enhance its capabilities, including a twin manipulator/ hydraulic assembly and an anode attachment package.

IUC's Recon comes standard with Harco silver-silver chloride cathodic protection probe and color video, with character generation, enhancing the quality of documentation for all types of inspections.

The Recon IV is one of the few RCVs designed with all its electronic components in the control console on the surface, eliminating the risk of water infiltration, which is *major factor in vehicle downtime.*

Forward, lateral and horizontal thrust is provided by four 1-HP motors with specially designed shrouds and propellers to produce up to 80 pounds of thrust which allows the vehicle to move at three knots. The vertical thruster can be controlled manually or automatically to provide constant depth hover control.

The Recon IV comes complete with its Tether Management System (TMS) and Handling System (HS). The TMS is a proven concept, acting as an umbilical depressor, allowing the vehicle to be de-coupled from the ship's motion during live boat operations. Another advantage of the TMS is that the vehicle mates below the cage which eliminates the need for it to orient itself to the cage. During recovery, in strong current, considerable time is therefore saved.

IUC's Recon IV capabilities include visual/Non-Destructive Testing (NDT) inspection, installation, maintenance, repair and salvage, on a variety of projects including production facilities, exploration rigs, pipeline and wrecks. By no means is the Recon IV limited to these tasks and IUC's vehicle engineers will be pleased to demonstrate Recon's capabilities for you on your next ROV requirement.

Additional equipment includes:
- Twin Manipulator Package
- Anode Placement Package
- Additional NDT Equipment
- Stereo 35mm or 70mm Camera
- Pipe Tracking Navigation System
- Assortment of Special Tools, including Cutters, Grinders and Wire Brushes.

Figure VI-3-2 The ROV "Recon IV"

Recon IV:

TABLE VI-3-2

2 ^00-Foot Remotely Operated Vehicle

Specifications:

General

Operating depth:	2,300 feet (701 meters)
Length o.a.:	6.5 feet (1.98 meters)
Breadth:	3 feet (.9 meters)
Height:	2.75 feet (.84 meters)
Weight in air (gross):	900 pounds (410 kilograms)
Speed, forward:	3 knots
Speed, lateral:	2 knots
Payload (wet):	250 pounds (114 kilograms)
Depth control:	Automatic or manual
Thrusters:	Four 1-HP electric (80 pound thrust)

Control Consoles (Pilot and Auxiliary)

Height:	5.75 feet (1.75 meters)
ʹth:	3.75 feet (1.14 meters)
ͻth:	3.5 feet (1.07 meters)
Weight:	1,800 pounds (816 kilograms)
Power requirements:	20 KVA, 60 Hz, 230 v 3-phrase
Portable consolette:	50 feet (extended) reach with controls for thrust pan, tilt, camera focus, flying tether payout, vehicle lighting and manipulator

Tether Management System

Operating depth:	2,000 feet (610 meters)
Diameter:	4.58 feet (1.4 meters)
Height:	4.33 feet (1.3 meters)
Weight in air (gross):	1,650 pounds (748.42 kilograms)
Tether drive motor:	1-HP electric (100 pounds pull)
Tether payout indicator:	Digital surface meter

Tether (Vehicle to Cage)

Length:	400 feet (121.9 meters)
Breaking strength:	4,000 pounds (1,814 kilograms)
Strength member:	Braided Kevlar
Weight in water:	Neutrally buoyant

Main Umbilical (Winch to Cage)

ʹgth:	2,200 feet (670.56 meters)
neter:	1.25 inches (3.18 centimeters)
Breaking strength:	30,000 pounds (13,607.8 kilograms)
Armor:	Contrahelically wound improved plough steel, two layers

Handling System

Type:	Hiab 1870 series Articulating Crane
Reach:	28 feet (9.14 meters)
Turning radius:	390 degrees
Capacity:	10 tons (9,071.85 kilograms)
Power:	Electric/Hydraulic-220/440 v 3-phase
Umbilical winch:	High strength steel, torque hub drive
Umbilical winch (capacity):	2,200 feet of 1.25 inch (670.56 m. of 3.18 centimeter) diameter cable
Dimension:	5 feet x 5 feet (1.52 m. x 1.52 m.)
Line speed (full drum):	100 feet/min. (30.48 meters/min.)

Work & Documentation

Manipulator:	one 4-function, two 5-function or one 7-function
Tools:	Hydraulic disk cutters, cable cutters, impact wrench, and other necessary tools
Television camera:	CM-8, CM40, CM50 or Osprey available (color or black & white)
Video recorder:	Two ½ inch cassette units
Video monitor:	12 inch (30.48 centimeters) color
Video annotation:	Date, time, depth, heading and CP
Remote video monitor:	Color or black & white at up to 50 feet (15.24 meters) away
Lighting:	Two 250 watt incandescent (variable-intensity), Mercury vapor option
Pan & tilt:	270 degrees pan, 180 degrees tilt
Pan & tilt (speed):	45 degrees per second
Still camera:	35mm, 70mm, or 35mm stereo camera available with strobe
NDT:	CP Probe Harco Model 1HRP-803

Navigation

Sonar:	Straza 250A
Compass:	Digicourse-Magnetic
Depth sensor:	0-2300 feet (0-701 meters) ± 0.5% of full scale

Table VI-3-3

Photographic system characteristics and calibration of field of view (FOV) for ROV and submersible survey systems.

Photographic System	Calibration on each vehicle: Recon IV[1,3]		Mermaid II[2]
35 mm still camera; 28 mm UW Nikkon behind corrected port; oblique angle of view.	$0.605\ m^2$		$0.176\ m^2$
	Tilt Angle	Area	
Color video camera; 12.5 mm lens; 65° angle of view	-044	$0.043\ m^2$/FOV	$1.225\ m^2$/FOV
	-032	0.086	
	-006	0.480	
	+006	0.0558	

1 - Still camera fixed mount; video on pan/tilt head.

2 - Still and video cameras on pan/tilt head which was held at 60° below horizontal for calibrated survey photography.

3 - Recon video FOV was determined by interpolation.

calibration grid was fixed forward on the Recon IV skids in a horizontal plane. The quadrat consisted of 10 cm, 5 cm and 2.5 cm grid squares from far field to near field (Fig. VI-3-3). Still photographs and a test series of pan/tilt video recordings were obtained with the vehicle submerged. Still (35 mm) and video images of the grid were traced on transparent plastic sheets for planimeter determination of photographic area of coverage for the different ROV optical systems. A table of tilt angles and areas of coverage for the video was constructed so that any instantaneous area of coverage for any tilt angle from a video transect could be interpolated.

The still and video camera systems on the submersible were calibrated by (1) setting the pan/tilt head to a predetermined angle (60^o below the horizontal); (2) placing a 0.25 m^2 grid with 5- and 10- cm calibration bars on the bottom; and (3) making a pass over the grid and taking still photographs and video footage (Fig. VI-3-4). Areas of coverage were determined by the same methods described above for the ROV.

To obtain species enumeration from ROV and submersible transect still imagery, photographs were taken as a representative series along the dive transects which produced high quality video. No comparison of resolution between the systems was attempted. Photographs were projected and all animals were enumerated to lowest possible taxon. Mean densities were computed for individual taxa. Densities were then standardized to number per m^2.

Video imagery was treated as a series of short strip transects within each dive. ROV tapes were reviewed and tilt angle was determined from the numeric annotation on the screen (Fig. VI-3-5). Submersible tapes were shot at a preset angle. Short transects were located on the tape with the camera forward looking and the ROV or submersible in contact with the bottom. A total transect was completed when five continuous fields of view (FOV) were observed on the screen. An FOV is defined as the closest point to the camera (bottom of monitor) to the horizon (farthest visible distance on the monitor). Area of coverage for a transect was computed by determining the instantaneous area of coverage for a video frame (FOV is 425 to 5575 cm^2 for ROV video imagery, 12250 cm^2 for submersible video imagery) and multiplying by 5. Water visibility and camera angle produced average transect lengths of lm $\pm$ .2 m. Animals were identified to the lowest possible taxon and mean density computed. Densities were then standardized to number per m^2. Table VI-3-3 sumarizes calibrations for each system.

Still and video documentation was stratified by habitat type for certain density determinations of key organisms (i.e. on/off dredged material, soft vs. hard substrate). Due to the irregular nature of bottom topography in hardrock and ledge areas, the imagery was obtained by piloting over the substrate rather than in contact. Although efforts to retain vehicle contact with the substrate were made, the height of camera lenses off bottom during these transects was more variable. Bias of

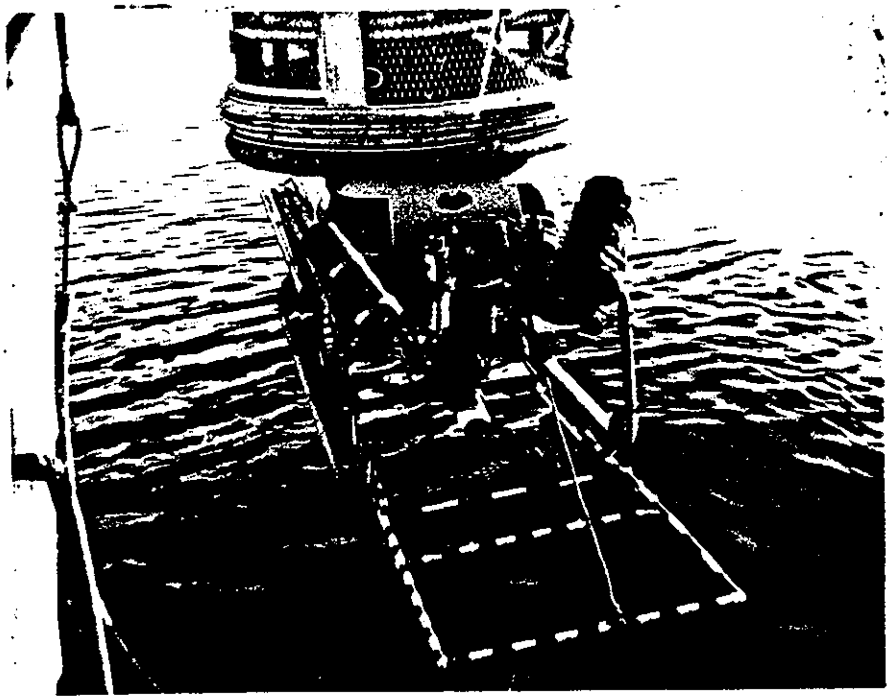


Figure VI-3-3. ROV "Recon IV" with port and starboard scale rods and horizantal grid for calibration of 35mm still and video photographic area.

Figure VI-3-4. The calibration grid for Mermaid II resting on the bottom. Still photographs and video were taken while passing over the grid in order to calibrate both imaging systems.

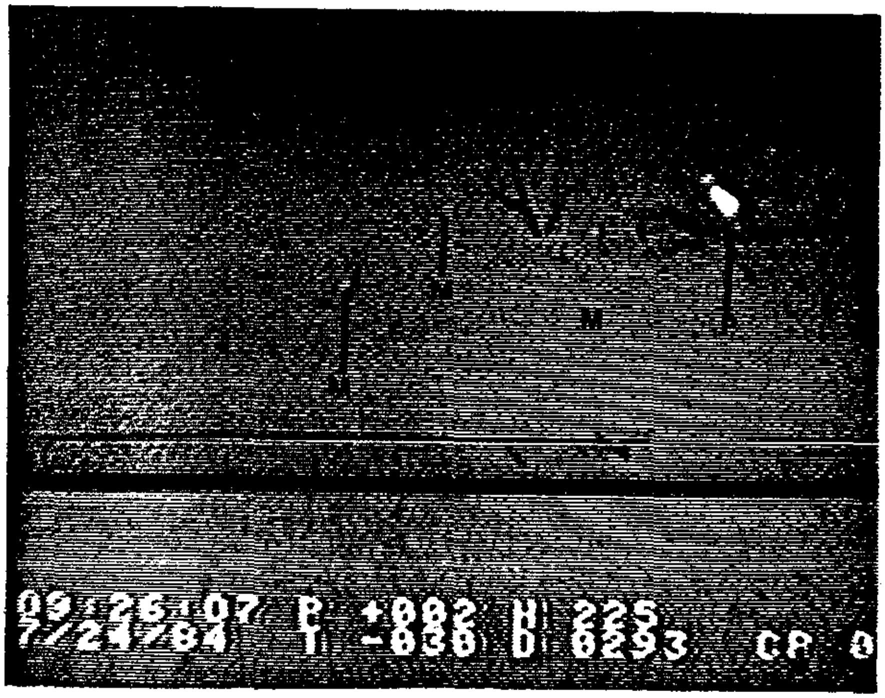


Figure VI-3-5. Video image illustrating cryptic nature of mysid (m) and panadalid (p) species in the transect path.

this nature will result in slight overestimates in density computations.

In addition to species quantification, observations of faunal-substrate relationships, behavior, small-scale substrate variability, and border locations were made from still and video documentation.

Delineation of the disposed mound border was determined visually from the submersible using the precision navigation plot or from real-time viewing of the ROV video image. Positions of the border and of the submersible vehicle track at each site were determined with a Honeywell submersible positioning system (RS-7) and Del Norte microwave navigation system interfaced to the SAIC Navigation and Data Aquisition System which included an X-Y plotter and printer. Positions of the ship were acquired from the microwave navigation system and, when integrated with distance and bearing of the submersible vehicle yielded a fix plot of the submersible track over the bottom at a rapid update rate.

4.0 RESULTS

From 23-28 July 1984, nine manned submersible dives and sixteen ROV dives were completed during the cruise at the three disposal sites as shown in Table VI-4-1. Tasks accomplished included:

- Surveys on and off dredged material at each site allowing major habitat descriptions, descriptions of unique faunal-substrate relationships, and quanitiative assessment of faunal groups utilizing the sites. Particular attention was directed to distributional and behavioral observations of important commercial fishery resources.

- Visual delineation of dredged material perimeters (tracked with precision navigation system) as ground truth for remote batymetric methodologies.

- Comparison of manned submersible and ROV vehicles for use in monitoring deep water dredged material disposal sites, within DAMOS program.

During survey operations, approximately 1800 frames of 35mm transparancy film were exposed (Table VI-4-2) and approximately 30 hours of video tape recorded (Table VI-4-3) to provide documentation of conditions at these sites.

Submersible positioning and tracking provided accurate vehicle location and charting in relation to major substrate features at the site (i.e. dredged material border, faunal concentrations, acoustic targets etc.) (Figures VI-4-1 and VI-4-2, Tables VI-4-4, 5 and 6).

TABLE VI-4-1. Summary of dive operations conducted from R/V ALOHA, Gulf of Maine, July, 1984.

M = Mermaid II
R = Recon IV

Number following designates dive number

Date	Site	Dive Ops.	
7/23/84	Foul Area	R1	East of disposal buoy
		R2	Northeast of disposal buoy
		R3	Reference site
		M1	Center of pile to E
		M2	SW of CG buoy
7/24/84	Foul Area	R4	100 m N of end of M2
		R5	SW drift to dive M2 end point
		M3	500 m N, 200 m W of target area
7/25/84	Foul Area	R6	Target area to NW of disposal buoy
		M4	Target site
		M5	Target site
		R7	ROV calibration
		R8	South disposal site
7/26/84	Cape Arundel	M6	North side survey
		M7	South side survey
7/27/84	Portland Disposal Site	M8	Border delineation
		M9	South side to NE
		R9	SW to NE survey
		R10	Reference site
7/28/84	Portland Disposal Site	R11	NE to S survey
		R12	NE to S survey
		R13	NE to S survey
		R14	NE to S survey
		R15	Hardrock rise S of site
		R16	Hardrock rise S of site

TABLE VI-4-2. Summary of 35 mm film documentation obtained during submersible/ROV operations from R/V ALOHA, Gulf of Maine, July, 1984.

Roll No.	Date	Dive	Notes	Ektachrome 200 Processing
1	7/23	R1, R2 R3	Recon dives	Push 1 stop
2	7/23 7/24	M1, M2 R4, R5	Fr 0-60 Mermaid Dives 1 & 2, 61 to end Recon IV dive	Push 1 stop
3	7/24 7/25	M3, P6 M4, M5	Fr 1-16 Mermaid Dives 17-180 Recon Dives. 181 to end Mermaid dives. 4 & 5 f/11 3 ft	Push 1 stop
4	7/25 7/26	R7, R8 M6	0-176 Recon Dives. Data chamber reset 0 to end. Mermaid Dive #6 on 7/26 f/11	Push 1 stop
5	7/26 7/27	M7, M8	Frames 0-109 Mermaid Dive 7. Reset 0 to 3rd M8 on 7/27 f/11	Push 1 stop
6	7/27	M9, R9 R10	0-63 Mermaid 64 to end Recon 3 ft. f/11.5	Push 1 stop
7	7/28	R11	Morning recon dive stereo shots 3 ft. f/8.5 200 ASA	Rated ASA
8	7/28	R12, R13 R14, R15 R16	3 ft. f/8.5 200 ASA	Rated ASA

ABLE VI-4-3. Summary of video documentation obtained during submersible/ROV operations from R/V ALOHA, Gulf of Maine, July, 1984.

Casette Number	Date	Dive	
1	7/23	R1, R2, R3	E and NE transects. Reference site. FA.
2	7/23	M1	Center of pile to east. FA.
3	7/23	M2	SW of CG buoy. FA.
4	7/24	R4, R5	NE and SW survey over disposal site mound. FA.
5	7/24	M3	500 m N, 200 m W of target area. FA.
6	7/24	M3	500 m N, 200 m W of target area. FA.
7	7/25	R6, R7, R8	NW survey, calibration, S. site. FA.
8	7/25	R8	Continued from tape 7, S. site survey.
9	7/25	M4	NW area. FA.
10	7/25	M5	NW area. FA.
11	7/26	M6	North site survey. Cape Arundel.
12	7/26	M7	South site survey. Cape Arundel. External camera.
13	7/26	M7	South site survey. Cape Arundel. Internal camera.
14	7/27	M8	Border delineation PDS.
15	7/27	M9	SW to NE bound survey. PDS. External camera.
16	7/27	M9	SW to NE mound survey. PDS. Internal camera.
17	7/27	R9	SW to NE survey. PDS.
18	7/27 7/28	R10, R11 R12	Reference stn., NE to S surveys.
19	7/28	R13, R14 R15, R16	Site survey and S knoll surveys

SAIC

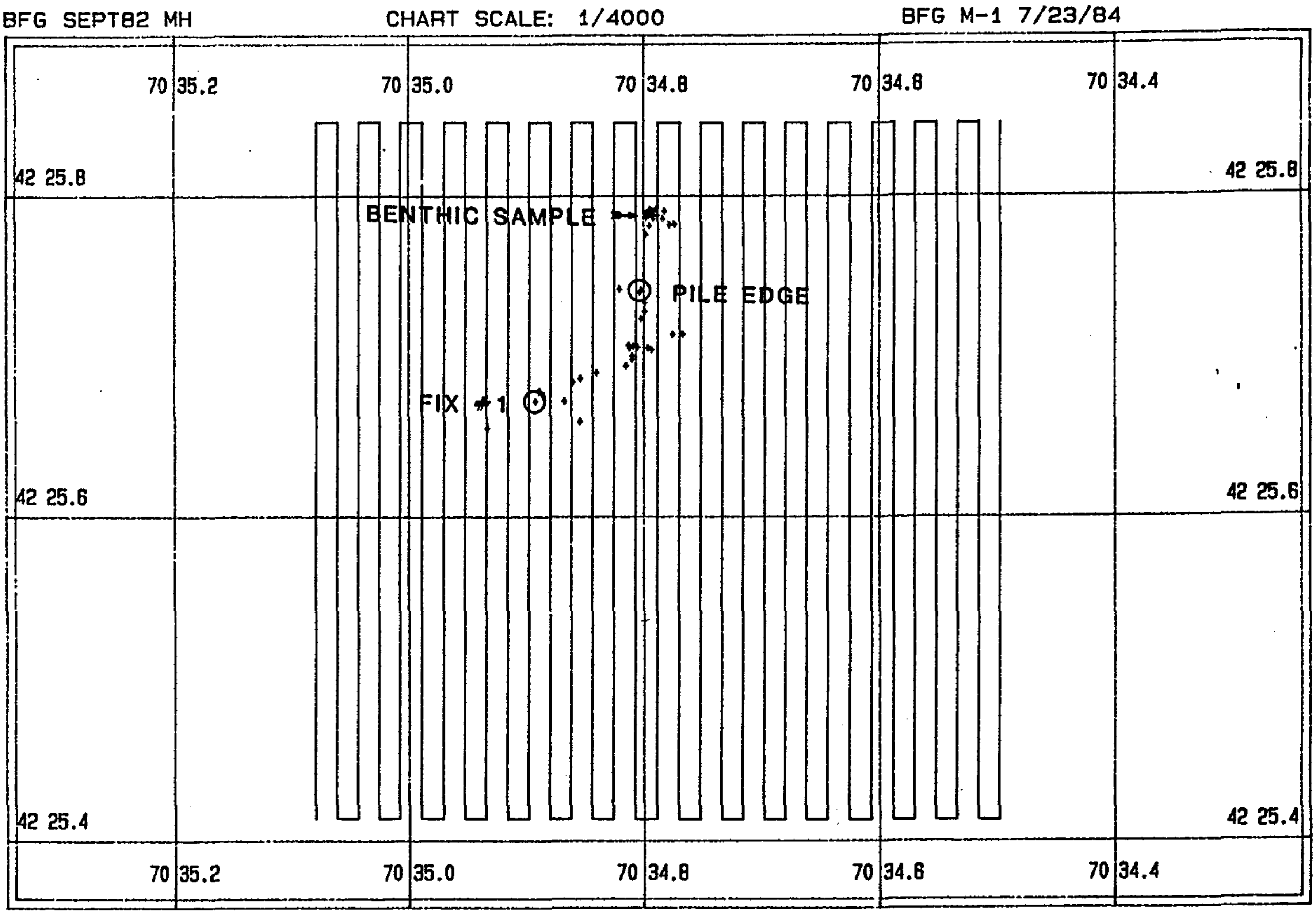


FIGURE VI-4-1. Representative plot of submersible tracking operation.

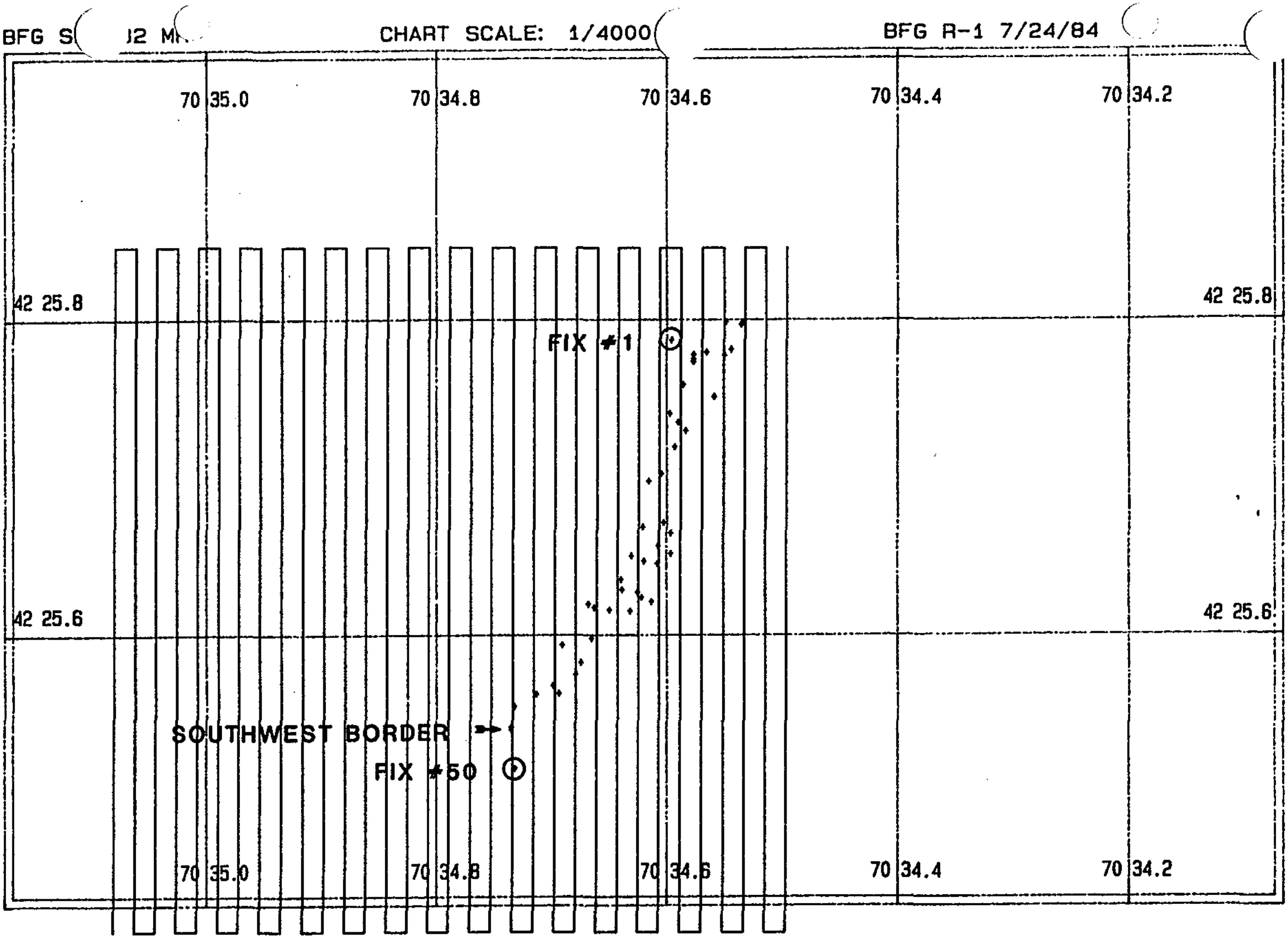


FIGURE VI-4-2. Representative plot of ROV tracking operation.

TABLE VI-4-4. Representative printout of Submersible Tracking operation.

10-15-84 SUBMERSIBLE OPERATIONS

---- DISPOSAL SITE: : 1 BFG ----
---- DATE: : 07-23-84 ----
---- DIVE: : M-1 ----

DISPOSAL SITE	DATE	DIVE	TIME	FIX NUM	SUB LAT	SUB LON	SUB X COORD	SUB Y COORD	REMARKS
BFG	07-23-84	M-1	1412	1	42.2567N	70.3489W	20791	-8576	
BFG	07-23-84	M-1	1415	2	42.2568N	70.3489W	20795	-8565	
BFG	07-23-84	M-1	1420	3	42.2567N	70.3489W	20800	-8570	
BFG	07-23-84	M-1	1422	4	42.2560N	70.3493W	20734	-8607	
BFG	07-23-84	M-1	1422	5	42.2567N	70.3487W	20825	-8576	
BFG	07-23-84	M-1	1424	6	42.2566N	70.3485W	20843	-8599	
BFG	07-23-84	M-1	1427	7	42.2568N	70.3486W	20835	-8554	
BFG	07-23-84	M-1	1428	8	42.2568N	70.3485W	20844	-8550	
BFG	07-23-84	M-1	1428	9	42.2569N	70.3484W	20863	-8543	
BFG	07-23-84	M-1	1433	10	42.2574N	70.3482W	20889	-8445	
BFG	07-23-84	M-1	1434	11	42.2570N	70.3480W	20910	-8513	
BFG	07-23-84	M-1	1434	12	42.2571N	70.3481W	20905	-8512	
BFG	07-23-84	M-1	1436	13	42.2571N	70.3481W	20900	-8511	
BFG	07-23-84	M-1	1440	14	42.2569N	70.3481W	20897	-8535	
BFG	07-23-84	M-1	1441	15	.......N	.......W	.....	.....	
BFG	07-23-84	M-1	1443	16	42.2570N	70.3480W	20922	-8514	
BFG	07-23-84	M-1	1446	17	42.2570N	70.3481W	20901	-8514	
BFG	07-23-84	M-1	1450	18	42.2570N	70.3481W	20904	-8527	
BFG	07-23-84	M-1	1452	19	42.2570N	70.3481W	20904	-8523	
BFG	07-23-84	M-1	1454	20	42.2570N	70.3479W	20926	-8516	
BFG	07-23-84	M-1	1456	21	42.2571N	70.3477W	20962	-8498	
BFG	07-23-84	M-1	1457	22	42.2571N	70.3478W	20950	-8498	
BFG	07-23-84	M-1	1459	23	42.2572N	70.3480W	20914	-8480	TURN NORTH
BFG	07-23-84	M-1	1500	24	42.2573N	70.3480W	20918	-8471	
BFG	07-23-84	M-1	1501	25	42.2573N	70.3480W	20918	-8461	
BFG	07-23-84	M-1	1502	26	.......N	.......W	.....	.....	
BFG	07-23-84	M-1	1502	27	42.2574N	70.3480W	20912	-8449	PILE EDGE
BFG	07-23-84	M-1	1503	28	42.2574N	70.3480W	20914	-8446	
BFG	07-23-84	M-1	1504	29	.......N	.......W	.....	.....	
BFG	07-23-84	M-1	1508	30	42.2578N	70.3477W	20952	-8369	
BFG	07-23-84	M-1	1509	31	42.2578N	70.3478W	20946	-8370	
BFG	07-23-84	M-1	1511	32	42.2579N	70.3479W	20925	-8357	
BFG	07-23-84	M-1	1511	33	42.2579N	70.3479W	20928	-8363	
BFG	07-23-84	M-1	1513	34	42.2579N	70.3478W	20939	-8363	
BFG	07-23-84	M-1	1515	35	42.2579N	70.3478W	20941	-8354	
BFG	07-23-84	M-1	1516	36	42.2579N	70.3479W	20933	-8359	
BFG	07-23-84	M-1	1519	37	42.2578N	70.3480W	20919	-8381	
BFG	07-23-84	M-1	1520	38	42.2578N	70.3480W	20923	-8371	
BFG	07-23-84	M-1	1522	39	42.2579N	70.3479W	20932	-8351	
BFG	07-23-84	M-1	1523	40	42.2579N	70.3479W	20926	-8358	BENTHIC SAM

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1 WASHINGTON ST. NEWPORT RHODE ISLAND 02840
401-847-4210

TABLE VI-4-4 cont.

10-15-84 SUBMERSIBLE OPERATIONS

- - - - DISPOSAL SITE: : 1 BFG - - - -
- - - - DATE: : 07-23-84 - - - -
- - - - DIVE: : M-1 - - - -

DISPOSAL SITE	DATE	DIVE	TIME	FIX NUM	SUB LAT	SUB LON	SUB X COORD	SUB Y COORD	REMARKS
BFG	07-23-84	M-1	1526	41	42.2579N	70.3479W	20928	-8358	OFFSET CHAN
BFG	07-23-84	M-1	1528	42	42.2579N	70.3480W	20923	-8359	
BFG	07-23-84	M-1	1529	43	42.2579N	70.3480W	20923	-8356	
BFG	07-23-84	M-1	1531	44	42.2579N	70.3479W	20924	-8353	
BFG	07-23-84	M-1	1532	45	42.2579N	70.3479W	20927	-8354	
BFG	07-23-84	M-1	1534	46	42.2579N	70.3480W	20923	-8359	
BFG	07-23-84	M-1	1536	47	42.2579N	70.3480W	20919	-8357	
BFG	07-23-84	M-1	1538	48	42.2579N	70.3480W	20920	-8360	
BFG	07-23-84	M-1	1540	49	42.2579N	70.3480W	20920	-8362	
BFG	07-23-84	M-1	1541	50	42.2579N	70.3480W	20921	-8356	
BFG	07-23-84	M-1	1542	51	42.2579N	70.3480W	20922	-8358	FINAL FIX

- - - - - - M-1 -

TABLE VI 4-5. Representative printout of ROV Tracking Operation.

10-15-84 SUBMERSIBLE OPERATIONS

- - - - DISPOSAL SITE: : 1 BFG - - - -
- - - - DATE: : 07-24-84 - - - -
- - - - DIVE: : R-1 - - - -

DISPOSAL SITE	DATE	DIVE	TIME	FIX NUM	SUB LAT	SUB LON	SUB X COORD	SUB Y COORD	REMARKS
BFG	07-24-84	R-1	0903	1	42.2579N	70.3460W	21197	-8359	
BFG	07-24-84	R-1	0905	2	42.2577N	70.3458W	21223	-8384	
BFG	07-24-84	R-1	0908	3	42.2578N	70.3454W	21267	-8370	
BFG	07-24-84	R-1	0910	4	.......N	.......W	.....	.....	
BFG	07-24-84	R-1	0911	5	42.2580N	70.3454W	21278	-8341	
BFG	07-24-84	R-1	0913	6	42.2580N	70.3453W	21282	-8339	
BFG	07-24-84	R-1	0915	7	42.2580N	70.3455W	21260	-8338	
BFG	07-24-84	R-1	0917	8	42.2578N	70.3455W	21259	-8377	
BFG	07-24-84	R-1	0919	9	42.2578N	70.3457W	21238	-8373	
BFG	07-24-84	R-1	0921	10	42.2578N	70.3458W	21223	-8381	
BFG	07-24-84	R-1	0923	11	42.2578N	70.3458W	21223	-8376	
BFG	07-24-84	R-1	0924	12	42.2575N	70.3456W	21247	-8425	
BFG	07-24-84	R-1	0926	13	42.2576N	70.3459W	21211	-8411	
BFG	07-24-84	R-1	0928	14	42.2574N	70.3459W	21205	-8455	
BFG	07-24-84	R-1	0930	15	42.2574N	70.3460W	21195	-8445	
BFG	07-24-84	R-1	0932	16	42.2572N	70.3459W	21201	-8484	
BFG	07-24-84	R-1	0934	17	42.2573N	70.3458W	21214	-8465	
BFG	07-24-84	R-1	0936	18	42.2570N	70.3460W	21185	-8516	
BFG	07-24-84	R-1	0938	19	.......N	.......W	.....	.....	
BFG	07-24-84	R-1	0940	20	.......N	.......W	.....	.....	
BFG	07-24-84	R-1	0942	21	42.2567N	70.3460W	21188	-8574	
BFG	07-24-84	R-1	0944	22	42.2570N	70.3462W	21170	-8525	
BFG	07-24-84	R-1	0946	23	42.2566N	70.3460W	21197	-8586	
BFG	07-24-84	R-1	0948	24	.......N	.......W	.....	.....	
BFG	07-24-84	R-1	0950	25	42.2566N	70.3461W	21182	-8601	
BFG	07-24-84	R-1	0952	26	42.2565N	70.3461W	21181	-8622	
BFG	07-24-84	R-1	0954	27	42.2565N	70.3460W	21197	-8610	
BFG	07-24-84	R-1	0956	28	42.2567N	70.3462W	21163	-8579	
BFG	07-24-84	R-1	0958	29	42.2565N	70.3462W	21165	-8619	
BFG	07-24-84	R-1	1000	30	42.2565N	70.3463W	21150	-8613	
BFG	07-24-84	R-1	1002	31	42.2563N	70.3463W	21157	-8656	
BFG	07-24-84	R-1	1004	32	42.2564N	70.3464W	21137	-8641	
BFG	07-24-84	R-1	1006	33	42.2562N	70.3462W	21162	-8662	
BFG	07-24-84	R-1	1008	34	42.2562N	70.3461W	21174	-8667	
BFG	07-24-84	R-1	1010	35	42.2563N	70.3464W	21138	-8653	
BFG	07-24-84	R-1	1012	36	42.2561N	70.3463W	21148	-8678	
BFG	07-24-84	R-1	1014	37	42.2562N	70.3465W	21123	-8677	
BFG	07-24-84	R-1	1016	38	42.2562N	70.3466W	21105	-8674	
BFG	07-24-84	R-1	1018	39	42.2562N	70.3467W	21098	-8670	
BFG	07-24-84	R-1	1020	40	42.2560N	70.3467W	21102	-8710	
BFG	07-24-84	R-1	1024	41	42.2559N	70.3469W	21067	-8718	

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TABLE VI-4-5 cont.

10-15-84 SUBMERSIBLE OPERATIONS

---- DISPOSAL SITE: : 1 BFG ----
---- DATE: : 07-24-84 ----
---- DIVE: : R-1 ----

DISPOSAL SITE	DATE	DIVE	TIME	FIX NUM	SUB LAT	SUB LON	SUB X COORD	SUB Y COORD	REMARKS
BFG	07-24-84	R-1	1026	42	42.2558N	70.3468W	21089	-8739	
BFG	07-24-84	R-1	1028	43	42.2557N	70.3468W	21083	-8753	
BFG	07-24-84	R-1	1030	44	42.2557N	70.3470W	21056	-8766	
BFG	07-24-84	R-1	1032	45	42.2556N	70.3469W	21063	-8775	
BFG	07-24-84	R-1	1034	46	42.2556N	70.3471W	21036	-8776	
BFG	07-24-84	R-1	1036	47	42.2555N	70.3473W	21010	-8790	
BFG	07-24-84	R-1	1038	48	42.2554N	70.3474W	21007	-8817	
BFG	07-24-84	R-1	1040	49	42.2554N	70.3474W	21007	-8814	SW BORDER
BFG	07-24-84	R-1	1044	50	42.2552N	70.3473W	21011	-8862	FINAL FIX

------ R-1 ------------------------------------
------ 07-24-84 ------------------------------------

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TABLE VI-4-6

Example of video narrative log from continuous video transect of substrate at Foul Area.

Recon IV, Dive R5. NE to SW survey over central disposal area.

Time Interval	Tape Index	Description
09:55:59	1066	smooth floculent sediment; 15 mysids/FOV decapod tracks over substrate surface, D=294'
09:57:31	1088	anthropogenic litter
09:58:05	1096	Pleuronectid fbunder, swimming foward
09:58:44	1105	Frequent worm tubes, approx. 5 cm high; 2 mysids/FOV
09:59:28	1116	15 mysids/FOV
10:00:04	1124	small (15 cm dia.) clay clump (intersecting border)
10:00:16	1127	*Urophycis* sp.
10:01:51	1149	*Cancer* sp.; mysids 15/FOV;tall worm tubes;D=295'
10:02:17	1155	large hake; density of clay clumps increasing
10:03:43	1175	field of clay clumps 10 cm to 1 m length
10:05:36	1201	Pandalid shrimp swimming;clay clumps continuing
10:11:05	1275	clay clumps continuing;tree branch material; 1 to 2 cm silt overlay on clay clump material; clumps are angular and not eroded;little evidence of bioerosion
10:15:25	1331	clay clump field continuing; Cancer crab walking across screen field
10:18:52	1375	Pandalid shrimp swimming around clump material
10:34:45	1448	Clay clumps continuing; snake blenny in field
10:27:40	1483	ROV measuring clay clump (10 cm dia.); snake blenny swimming across FOV;Pandalid shrimp
10:31:05	1523	Small burrow excavated beneath clay clump
10:36:24	1585	Pandalid shrimp next to clay clump
10:36:59	1592	1 snake blenny
10:38:30	1609	2 Asteroids
10:48:18	1630	Pandalid in surface depression

In conjunction with time coordinated video, still photographs and audio documentation for each dive, it is possible to precisely locate the position of any feature observed on a bottom traverse. The only problems encountered during tracking operations were intermittent loss of signals from the submersible vehicle caused by surface turbulence (due to rough seas and maneuvers of the ship).

Each dive provided the opportunity to accomplish several tasks: delineation of the mound border, qualitative and quantitative photographic documentation of geological and biological features, and behavioral interactions of the megafauna with the substrate. Table VI-4-7 presents representative data derived from individual dives of Mermaid II and Recon IV vehicles. Examples of transect photographs observed during dives are presented in Appendix VI. Each vehicle provided different perspectives of conditions on the bottom on a real-time basis. The frame of reference and resolution of specific features and organisms was distinct between the two vehicles. Table VI-4-8 compares and contrasts the documentation ability of both submersible vehicles in light of this cruise. In many areas, system capabilities are overlapping and complimentary for full documentation of the benthic conditions.

A variety of operational and logistic problems were encountered during this operation, as would be expected while developing or adapting new survey methodologies. Video and still photographic systems requires several operational changes. As a result of restricted visibilty caused by significant near bottom (10 m band) turbidity at the Boston Foul Ground site, the configuration of the video/still system aboard the Mermaid II was shifted from the upper bumper to the lower port manipulator mount. This lower camera position improved the angle of view, color saturation and resolution. Constant removal and servicing of both still and video systems require addition of machined mounting marks to assure replacement of cameras in the standard position.

The hydraulic power and precise control of the Mermaid II manipulator arm was insufficient to easily conduct coring operations. Consequently, little core sampling was accomplished.

4.1 Foul Area Site

Both ROV and submersible surveys indicated the positions of visually detectable dredged material borders. At the north (hopper disposal) site, a maximum NW-SE transect diameter of 0.5 km was obtained with an estimate of direct dredged material impact of 200,000 m^2. At the south (scow disposal) site, a maximum SW-NE diameter of 0.2 km was obtained, with an estimate of 30,000 m^2 impact area. Visual indications of peripheral mound limits were correlated with remote bathymetry estimates of dredged material dispersion.

Topographic relief throughout the area ranged within ± 2 m and isolated 1 m dredged clay blocks protruded above the

TABLE VI-4-7

Data derived from Recon IV and Mermaid II submersible operations at Foul Area.

I. Recon IV (Dive R5) Foul Area. Transect on natural bottom to dredged material area from southwest.

- Delineate Border - 42° 25.54' N 70° 34.74' W
- Density of motile macrobenthic fauna - Densities per 15 cm width x 90 cm length video field - (0.135 m^2).

	Off Mound		On Mound	
	Neomysis americana	Pandalid sp.	Neomysis americana	Pandalid sp.
N	50	50	16	16
$\bar{X}$	12.78	0.300	13.87	0.062
($\bar{X}/m^2$)	(94.66)	(2.22)	(102.74)	(0.459
SD	9.21	(.614	8.69	0.250
Max.	32.00	2.00	32.00	1.00
Min.	0.00	0.00	3.00	0.00

No significant differences (t-test, $p > 0.10$) between on and off spoil densities of either species.

- Behavioral and Distributional Observations.
  - Greater than 95% of mysids observed within approximately 20 cm of substrate.
  - Pandalids aggregated around clay clump material on the disposal site. On spoil density enumeration greatly underestimates real density of this species.
  - Both species interact with substrate at nepheloid layer. Burial behavior leaves surfaces relatively unconsolidated.

TABLE VI-4-7 cont.

II. Mermaid II (Dives M4, M5) Foul Area. Transects over target area.

- Locate acoustic target 42° 25.95' N 70° 35.40' W
- Densities of megabenthic fauna - per 0.176 m^2 still camera frame.

	Dive M 4					Dive M 5				
	N	$\bar{X}$ ($\bar{X}/m^2$)	S.D.	Min.	Max	N	$\bar{X}$	S.D.	Min.	Max.
Mysid sp.	16	0.37 (2.102)	1.09	0.00	4.00	117	0 (0)	0	0	0
Pandalid sp.	16	0.437 (2.483)	0.892	0.00	3.00	117	0.564 (3.205)	0.913	0.00	4.00
Snake Blenny	16	0.062 (0.352)	0.250	0.00	1.00	117	0.043 (0.244)	0.203	0.00	1.00
Rockling	16	0 (0)	0	0	0	117	0.0085 (0.048)	0.0924	0.00	1.00
Pleuronectid Flounder	16	0 (0)	0	0	0	117	0.043 (0.244)	0.203	0.00	1.00
Cerianthus borealis	16	0 (0)	0	0	0	117	0.79 (4.480)	1.94	0.00	10.00

- Biological and Geological Observations
  - Spoil material in clay clumps eroding slowly, covered with floculant, silt material. Erosion rates much slower than shallow sites.
  - Large megabenthic species remobilize surficial sediments during normal behavioral repetoires, leaving surface relatively unconsolidated
  - Distribution of *Cerianthus borealis*, mud anenome, very aggregated in this area.

TABLE VI-4-8

Date type and use from Mermaid II (manned submersible) and Recon (ROV) photodocumentation systems.

ROV		Manned Submersible	
Video	Still (35 mm)	Video	Still (35 mm)
Continuous track transects from limit of visibility above bottom to sediment water interface.	Discrete Sample along transect path.	Continuous track transects from limit of visibility to height video system mounted on sub.	Discrete sample along transect path.
Resolve macro features to several millimeters (i.e. nepheloid layer, mysids).	Resolve macro feature to several millimeters (still photodocumentation).	Resolve megabenthic features (i.e. general topography, large megabenthic organisms).	Resolve megabenthic features (still photodocumentation).
Variable field of view on pan/tilt head (quantifiable) to allow search and alter track.	Fixed area of coverage (reduces inter-sample variance).	Variable field of view on pan/tilt head (quantifiable).	Variable field of view on pan/tilt head (quantifiable).
Unlimited documentation capability	Limited to 250 frames.	Limited documentation capability by battery strength.	Limited to 250 frames.
Annotation of pertinent data on video tape (i.e. depth, heading, time, pan/tilt angle). Audio annotation.	Numerical data chamber for dive no., frame, time.	No data annotation - Audio annotation.	Numerical data chamber for dive no., frame, time.

soft interspace sediment. A 1 cm nepheloid layer veneer covered the upper portion of faceted clay mounds and extensive decapod and finfish tracks on surficial sediment characterized the survey sites. A notable near bottom (10 m) turbidity layer was present. Bioturbation and resuspension of fine surficial sediments by various demersal taxa (megabenthic, macrobenthic, and infauna) contributed to the persistence of this layer.

Predominant small demersal organisms evident in ROV video footage included dense swarms of mysid and clusters of pandalid shrimp. Table VI-4-9 indicates densities of mysid and pandalid species calculated from still (35 mm) and video records on soft substrate. Mysid densities greater than 20.0/m^2 were calculated over 27 discrete (1 m $\pm$ .2 m) video sample transects per survey dive. Spatial variations for mysid concentrations were great over the selected footage sampled, and patchy aggregations on a scale of 0.5 m were detected. Distribution of these ubiquitous organisms throughout the survey area was consistent and did not indicate avoidance to dredged material substrate.

Mysids are important prey species for commercially important fish in the NW Atlantic. Little is known about small-scale horizontal variability in the distribution of these important demersal prey species. Data presented here demonstrates that distributions of mysids can be highly aggregated on the small-scale. Similarly, larval herring on Georges Bank are also highly aggregated with densities ranging from 10.3 to 290.4/100 m^3 (Colton et al., 1980). Small scale horizontal transect techniques with ROVs and submersibles are amenable to discerning small-scale horizontal variability in a variety of demersal predatory and prey species.

Densities of pandalid sp. shrimp indicate a less variable range (0-1.25/m^2) and a similar uniform distribution over survey sites. Distinct aggregations of 3-6 pandalid shrimp often occurred on small-scale prominence features of the sediment.

ROV macro-range video imagery was the only format producing data on distribution and densities of small (0.5 - 1.0 cm total length) mysid species. The moving image and fine scale resolution allowed several enumerations of individuals over a 1.0 m video path (see Fig. VI-3-5). Video records were also more dependable for the small (3-6 cm) and less frequent pandalid species. However, certain high quality 35 mm photographs produced detectable pandalid species for comparable density estimates. The significance of these data, in the scale of resolution and quantification possible for small (0.5 - 3 cm) motile epibenthos, yield information on distributional patterns and densities that would be undectectable by standard sampling methodologies.

Enumeration of benthic finfish on the Foul Area site were from representative series of still photographs and several video transects (approx. 1 m) . Density estimates for the six

Table VI-4-9

Population densities of predominant small epibenthic Mysid (sp.) and Pandalid (sp.) species on soft substrate at the Foul Area Site, July 1984.

Dive No./tilt angle	Mysid (sp.)		Pandalid (sp.)	
	Still	Video	Still	Video
R1 (Old disposal material) - 020°				
No. Samples	49	27	49	27
X/m^2	0	16.24	0.50	0.49
R2 (Old disposal material) - 020°				
No. Samples	42	27	42	27
X/m^2	0	20.65	0.83	0.88
R6 (Old disposal material) - 020°				
No. Samples	NA	27	NA	27
X/m^2		5.58		0.49
R8 (Active disposal site) - 025°				
No. Samples	NA	27	NA	27
X/m^2		7.71		1.25
M5 (Target site)				
No. Samples	114	NA	114	NA
X/m^2	0		3.41	

predominant fish observed on the site (Table VI-4-10) represents analysis of all usable still photographs and representative sections of video records. Distribution patterns produce specific fish abundance estimates ranked as follows: Lumpenus (snake blenny), Pleuronectidae (flounder), Enchelyopus cimbrius (fourbeard rockling), Macrozoarces americanus (eelpout), Sebastes marinus (redfish), and Urophycis (hake). No significant differences in distribution were noted on or off dredged material.

Unusual abundance of Lumpenus (Fig. VI-4-3) and Enchelyopus indicated these fish were more prevalent than expected from regional benthic trawl survey sampling. Retention of juvenile size groundfish (10-15 cm TL) is reported less than 15% for trawl census data (Smolowitz, 1983), and accounts for the higher densities observed. Also, economically important species (Pleuronectidae, Sebastes) were present in significant numbers on the site. Video and still imagery from both submersible and ROV surveys indicate mud anemones, Ceriathus borealis, occur in highly aggregated patches around the site.

A brief reconnaissance of an area suspected of containing radioactive waste canisters was conducted (dives M4 and M5). Evidence of several disintegrated 50 gallon steel drums was observed, but no cement encased containers were encountered.

4.2 Cape Arundel Disposal Area

Inspection of the south (historical) disposal site at Cape Arundel revealed sand-silt-clay inter-ridge sediment bounded by cobble which graded into exposed bedrock ridges (NW to SE orientation) (Fig. VI-4-4). Ridges had 3 to 5 m vertical relief with typical hard substrate epifauna. The sedimentary substrate was extensively burrowed, due to the cohesive nature of the old dredged material and created diverse habitat for fishery resources. For example, many of the hake (Urophycis sp.) encountered along transects on the sedimentary substrate occurred in mud burrows. These burrows are typical of those excavated by decapod crustaceans such as Cancer crabs and lobster. Also, many vertical burrows (Fig. VI-4-5), which are characteristic of deep burrowing shrimp, were observed. Total burrow density over this site was $0.49/m^2$. Fishing gear debris which was encountered along the transect course (e.g. gill net weights, trawl mesh, relict lobster pots, and anchors) indicates recent fishing activity over this site and its continued fishery potential for important species like winter flounder (Fig. VI-4-6).

The north (pre-designated) site is characterized by a coarse sand-filled basin, also bounded by cobble grading into exposed bedrock (Fig. VI-4-7). The surface was "dimpled" by shallow depressions (Fig. VI-4-8) characteristic of crustacean feeding excavations, although few individuals were observed along transects. This area has less diverse habitat than the south site due to the lack of mud burrows, which require very cohesive sediments.

Table VI-4-10

Densities of demersal finfish calculated from still (35mm) and video ROV transects on the Foul Area Disposal Site.

Species	N* Densities X/m^2 Still	Video
Lumpenus sp.	91	108
(snake blenny)	0	0.073
Pleuronectidae	91	108
(flounder)	0.014	0.059
Enchelyopus cimbrius	91	108
(fourbeard rockling)	0	0.025
Macrozoarces americanus	91	108
(eelpout)	0	0.025
Sebastes marinus	91	108
(red fish)	0	0.025
Urophycis sp.	91	108
(hake)	0.009	0.014

*N - Number of frames for still photographs; number of transect paths (5 FOVs) for video.

SAIC

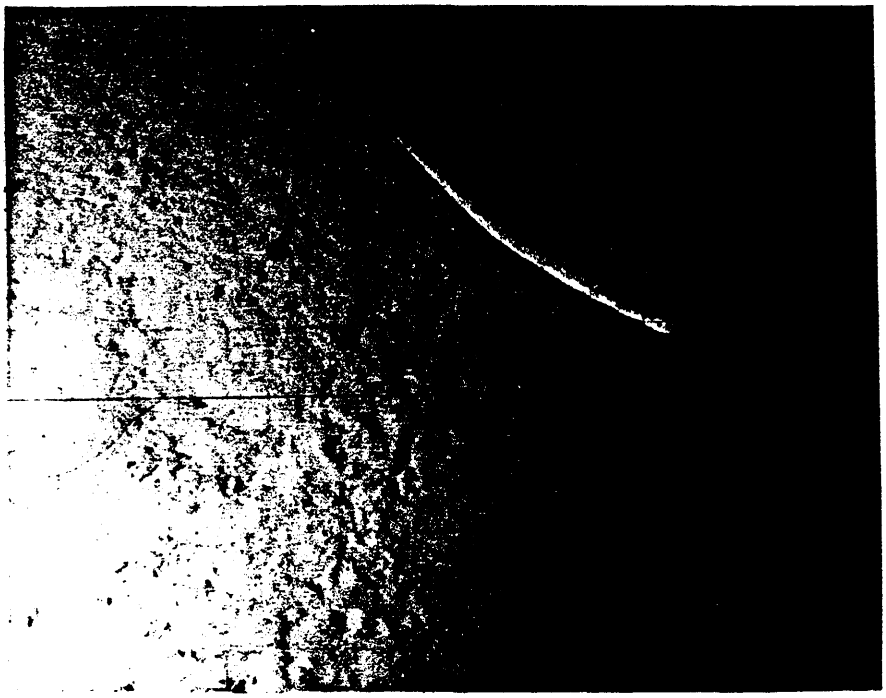

Figure VI-4-3. A snake blenny, Lumpenus lumpretaeformis, on the substrate surface at the Foul Area site. Normal burst swimming from an inactive start remobilizes surficial sediments to the water column.

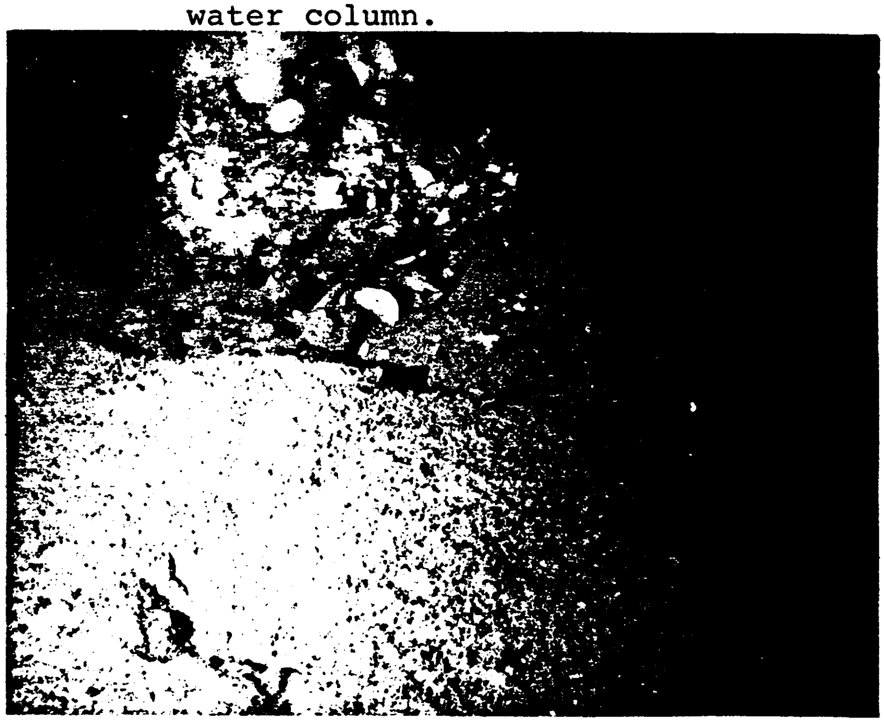

Figure VI-4-4. Rock-boulder habitat characteristic of the Cape Arundel south site perimeter. Note the complete epifaunal colonization of these surfaces.

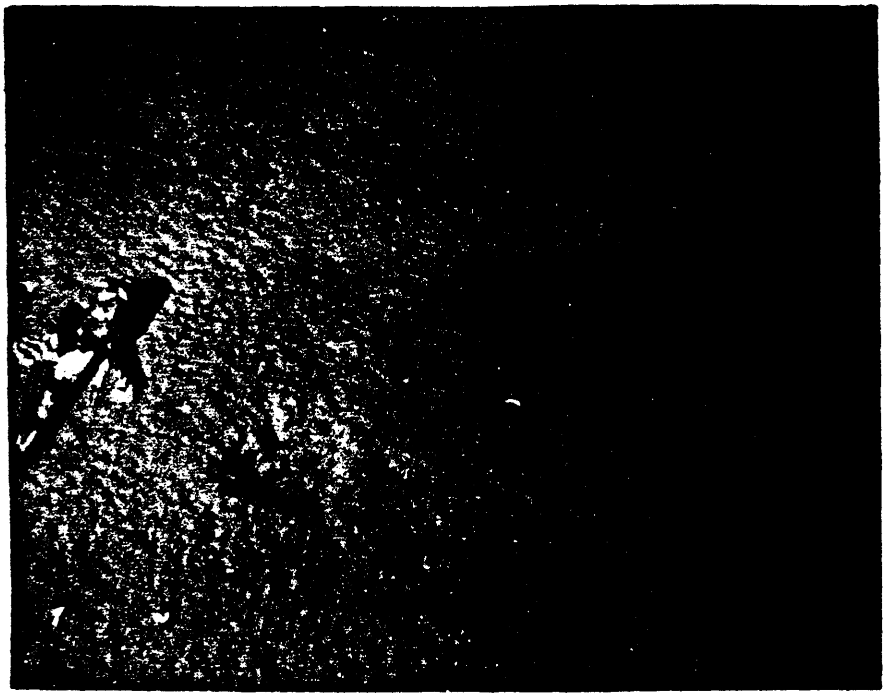

Figure VI-4-5. A sculpin, Myoxocephalus sp., near a 70 mm diameter vertical burrow at the Cape Arundel south site. A high density of burrows was observed at the site.

Figure VI-4-6. Winter flounder, Psuedopleuronectes americanus, on the sand-silt-clay substrate at the Cape Arundel south site.

Figure VI-4-7. Rock-boulder habitat along the periphery of Cape Arundel north site. Perimeter areas like this are good habitat for juveniles and adults of a variety of species.

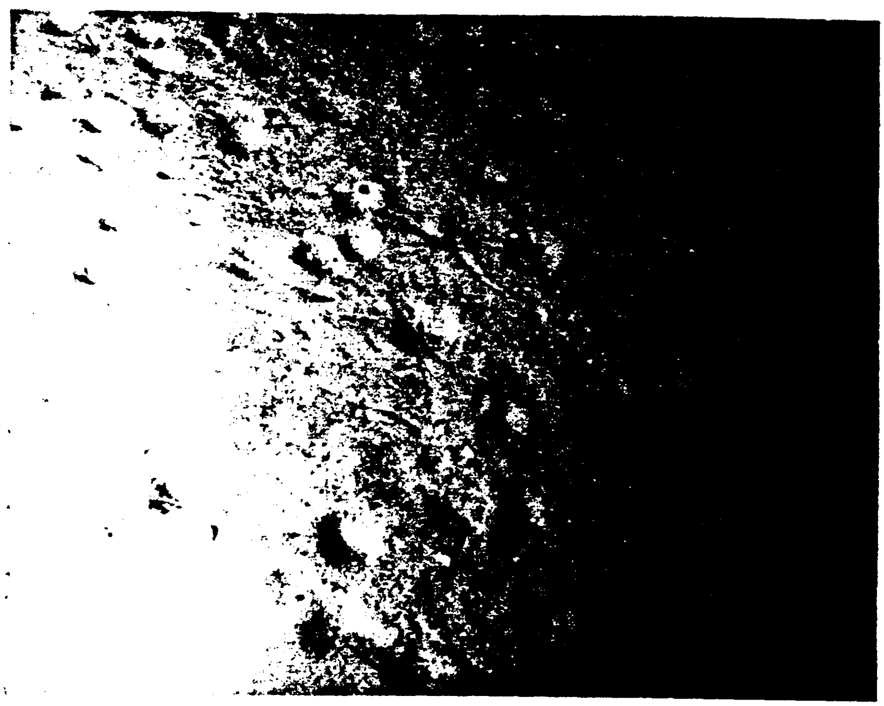

Figure VI-4-8. The "dimpled" sand bottom at the Cape Arundel north site. These depressions are characteristic of crustacean foraging for infaunal prey.

A comparison of the megabenthos enumerated during survey dives (Table VI-4-11) at both north and south sites reveals little difference in overall densities of species present with several numerically rare species occurring only at one of the two sites. This pattern can be attributed to the effect of the adjacent rock-cobble substrate providing habitat for many species. The soft substrate of the south site directly provides shelter for several species (e.g. hake). The north site, which is being considered for containment of dredged material, will be less impacted by disposal operations in terms of habitat loss than the historic south site.

4.3 Portland Disposal Site

The peripheral limits of the Portland disposal site were determined by ROV and submersible intercept with the natural bottom and the visible dredged material border (Fig. VI-4-9). The maximum diameters of clay coverage were 0.9 km (SW - SE) and 0.6 km (NE - SE) with an estimate of total area of coverage of 2.5×10^6 m^2. Topographic relief varied greatly over the designated disposal site, with exposed bedrock and boulder elevations of $\pm$ 4 m bounded by soft substrate.

Eleven different benthic finfish species are ranked by observed abundance on and off Portland disposal material (Table VI-4-12). No significant difference in species distribution was attributed to habitat preference in this evaluation. Biogenic sculpturing of dredged clay material was noted to create burrow habitat in border regions (Fig. VI-4-10).

Fish abundance estimates from combined still/video records with species values greater than $0.02/m^2$ would suggest the species examined are important in impact assessment and habitat association studies. Those would include the first five ranked species in Table VI-4-12: Urophycis (hake), Tautogolabrus (cunner), Myoxocephalus (sculpin), Macrozoarces (eelpout), and Gadus (cod).

The Portland site contained distinct regions of hard bedrock/boulder substrate with a diverse attached faunal assemblage (Fig. VI-4-11). The moderately shallow (50 - 65 m) depths revealed rather homogeneous distribution of sessile forms on exposed lateral and horizontal rock surfaces. Enumeration of different hard substrate organisms identified in both still and video records has been presented as density per m^2 (Table VI-4-13). Although statistical comparison would be inappropriate for data obtained from one ROV transect during one day, the high sample numbers (N) and comparable mean densities for the different organisms demonstrate the ROV (35 mm) still and video systems produced similar data for the sessile species listed.

Inspection of hard substrate video records immediately adjacent to cohesive clay dredged material showed no distinguishable decrease in the densities or distribution of

Table VI-4-11

Densities of predominant megabenthos at the Cape Arundel sites.

	Densities* (per m^2)			
	South Site (Historical site)		North Site (Pre-designated site)	
Species	Still (n=74)	Video (n=106)	Still (n=35)	Video (n=96)
Cerianthus borealis	0.36	0.61	0.07	0.82
Anthozoan spp.	1.33	0.41	0	0.07
Homarus americanus	0	0	0	0.01
Cancer sp.	0	0.01	0	0
Psuedopleuronectes americanus	0.18	0.04	0	0.04
Tautogolabrus adspersus	0	0.17	0	0.11
Prionotus sp.	0.09	0.01	0	0
Myoxocephalus sp.	0	0.08	0	0.07
Raja sp.	0	0.02	0	0
Macrozoarces americanus	0	0	0	0.07
Urophycis sp.	0.04	0.07	0.02	0.07
Sebastes sp.	0.09	0	0.02	0.01
Boltenia sp.	0	0.07	0	0
Asteroid spp.	0.93	0.31	0.09	0.24

*Sample size is number of frames for still photographs; number of transect paths (5 FOVs) for video.

Figure VI-4-9. Sediment micro-scale topography and peripheral mound habitat at the Portland site.

Figure VI-4-10. Benthic finfish (Urophycis sp.) within a burrow at dredged material border of the Portland site.

Table VI-4-12
Densities of demersal finfish calculated from still (35mm) and video (1/2") ROV transects, on and off disposal material at the Portland site.

Species	On Disposal Material Still	On Disposal Material Video	Off Disposal Material Still	Off Disposal Material Video
	Densities $\frac{N^*}{X/m^2}$			
Urophycis sp.	157 0.149	54 0.167	54 0.07	81 0.864
Tautogolabrus adspersus	157 0	54 0.098	54 0.03	81 0.086
Myoxocephalus sp.	157 0	54 0.063	54 0.03	81 0.012
Macrozoarces americanus	157 0.009	54 0.033	54 0.03	81 0.012
Gadus morhua	157 0	54 0.045	54 0	81 .307
Lumpenus sp.	157 0.030	54 0	54 0	81 0.025
Prionotus sp.	157 0.020	54 0.018	54 0	81 0
Pleuronectidae	157 0.029	54 0.018	54 0	81 0
Raja sp.	157 0	54 0.018	54 0	81 0
Sebastes marinus	157 0.020	54 0	54 0	81 0
Lophius americanus	157 0.911	54 0	54 0	81 0

*N = Number of frames for still photographs/ number of transect paths (5 FOVs) for video.

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Figure VI-4-11. Hard rock substrate of natural bottom adjacent to Portland dredged material mound.

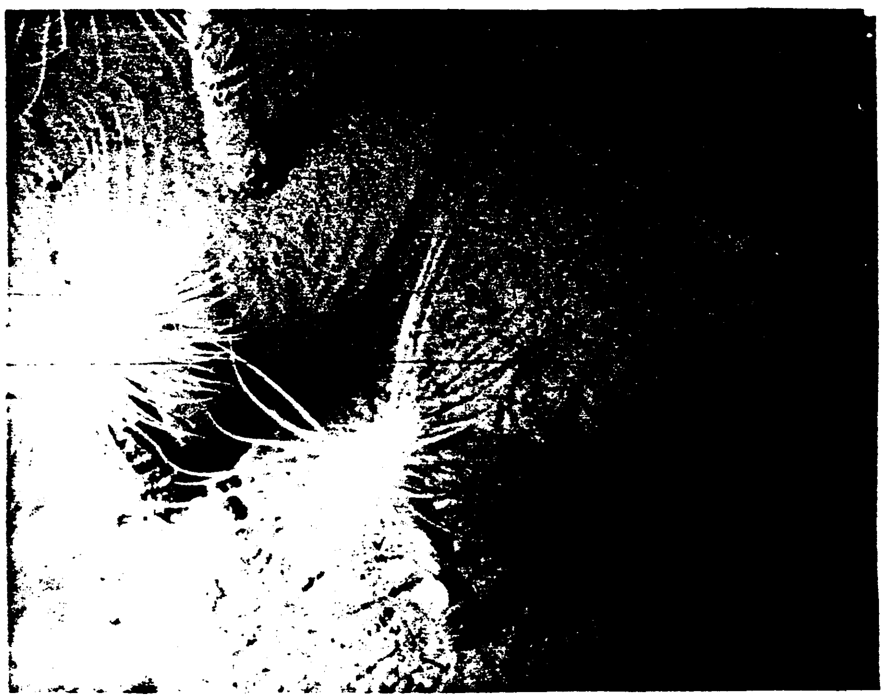

Figure VI-4-12. Cerianthus borealis "forest" at the Portland reference site. These aggregations provide habitat for other species, like the juvenile finfish at center left in the photograph, and enhance local species diversity.

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Table VI-4-13

Enumeration of hardrock substrate epifauna at peripheral regions at the Portland disposal site.

Species	Densities N* Still	X/m^2 Video
Metridium (anemone)	233	54
	0.65	0.43
Tealia (anemone)	233	54
	0.007	0.0005
Terebratulina (brachiopod)	233	54
	8.48	8.21
Boltenia (stalked ascidian)	233	54
	0.18	0.09
Polymastia (sponge)	233	54
	1.405	1.25
Porifera sp. (sponge generic)	233	54
	0.028	0.43
Asteroidea (seastar)	233	54
	0.68	0.51

*N = Number of frames for still photographs; number of transect paths (5 FOVs) for video

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attached fauna. Interference effects or halo zones around patch dredged material mounds were not observed. In-situ observation demonstrated abrupt change (approx. 2 m) from clay coverage to normal attached faunal communities.

At a reference site 1.8 km SE of the Portland disposal site, two unique biological conditions were observed that may reflect normal faunal/substrate interactions within the extensive 50 - 150 m depth Gulf of Maine soft sediment habitat. Dense communities of Cerianthus borealis have been located throughout the Northwest Atlantic continental shelf and distributions were reported to be highly aggregated with enhanced associate species diversity (Shepard et al. In review). Identification of cerianthids to species from distant manned submersible photography was often difficult. The ROV near field photographic systems produced high resolution records of epibiotic associates and accurate density/dimension values for a limited number of cerianthid "forests" encountered (Table VI-4-14) at the Portland reference station.

Mean density of Cerianthus borealis ($17.50/m^2$) calculated from 27 one meter video paths was considered a dense aggregation with a high density of associated organisms. Measurements of Cerianthus stalk and tentacle crown diameters were determined in-situ, by reference to the calibration rod scale as it passed directly by individual Cerianthus (Fig. VI-4-12). Measurements of sixteen Cerianthus to the nearest 0.5 cm gave a mean stalk diameter of 2.7 cm (range 1.0 - 4.0 cm) and mean tentacle crown diameter of 10.2 cm (range 4.0 - 15.0 cm).

An unusual juvenile cod (20-30 cm TL) behavioral interaction with the substrate was observed at the 90 m reference station. Individual fish were recorded at rest with ventral caudal portions of the body submerged in the soft surficial sediment (Fig. VI-4-13). On disturbance by the ROV pass, the juvenile cod would burst to a point approximately 3 m distant and resume the resting burial behavior. These observations, although limited, identify another key species responsible for significant sediment bioturbation due to thigmotactic behavior. The ROV video record also illustrates the importance of soft substrate as valuable juvenile codfish habitat for feeding or predator protection refuge.

5.0 SUMMARY

The combination of manned submersible, ROV and precision navigation-tracking systems provided a powerful tool for documenting megabenthic biological and geological conditions at deep water disposal sites. As on surveys conducted with SCUBA techniques, it was possible to delineate the physical impact area of dredged material disposal operations on the seafloor (Table VI-5-1). Manned submersible and ROV techniques allowed greater time available for detailed inspection, observation and documentation of conditions by providing the following

Table VI-4-14

Ceriantbus borealis (mud anemone) community densities and associate organisms at the Portland reference station.

Species	Density (X/m^2) From Video Transects (N = 27)
Cerianthus borealis (mud anemones)	17.5*
Pandalid sp. (shrimp)	0.58
Mysid sp. (crustacea)	3.06
Gadus morhua (cod)	0.92
Tautogolabrus adspersus (cunner)	0.19
Lumpenus sp. (snake blenny)	0.04
Porifera (sponge)	15.44
Terebratulina (brachiopod)	0.84

*Measurements of 16 C. borealis to nearest 0.5 cm from video imagery yielded mean stalk diameter of 2.65 cm (range 1- to 4- cm) mean tentacle crown (tip to tip across disc) diameter of 10.16 cm. (range

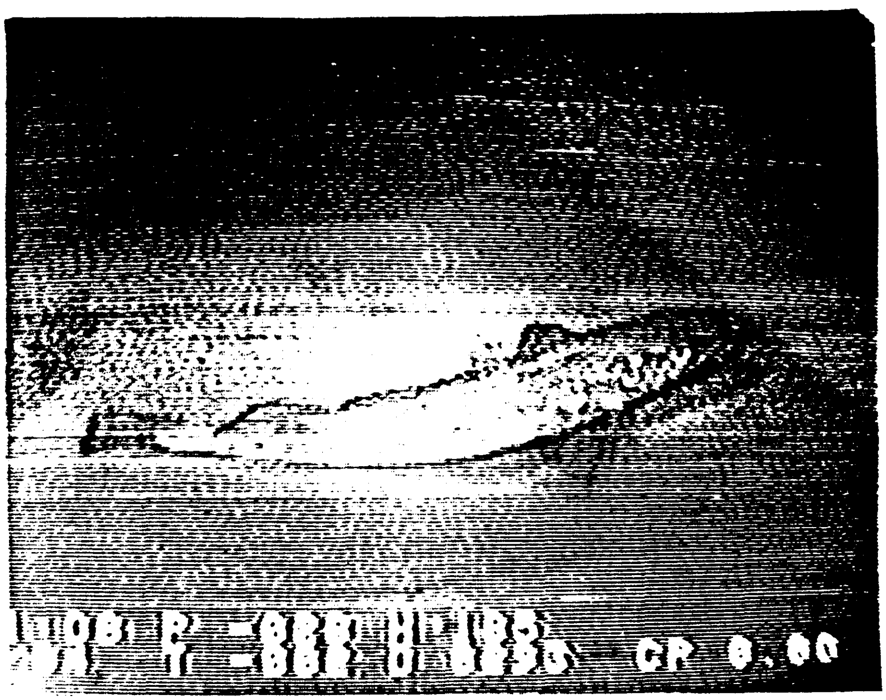

Figure VI-4-13. Video image of juvenile cod, Gadus morhua, in resting posture on substrate.

Table VI-5-1

Dredged Material Border and Site Delineation determined by submersible and ROV survey, July, 1984.

SITE	LATITUDE	LONGITUDE	DIVE
Foul Area			
- North Site	42° 25.73' N	70° 34.80' W	M1
Northeast Border	42° 25.78	70° 34.80	
	42° 25.79	70° 34.80	
Southwest Border	42° 25.66	70° 34.60	R5
	42° 25.54	70° 34.74	
- South Site	42° 25.08	70° 34.70	R8
Northeast and South Borders	42° 25.08	70° 34.67	
	42° 25.01	70° 34.76	
Cape Arundel			
- North Site (Predesignated Site)			
East Edge of sand substrate (Start Rock Ledge)	43° 18.04	70° 27.17	M6
West Edge of sand substrate	43° 18.00	70° 27.26	
- South Site (Historical Site) West Rock Ledge Begins	43° 17.75	70° 27.23	M7
West Edge of mud substrate	43° 17.68	70° 27.34	
	43° 17.67	70° 27.33	
Portland Disposal Site			
Western apron - clay clumps	43° 34.13' N	70° 02.49' W	M8
Western border (all clay clumps)	43° 34.07	70° 02.35	
Eastern border	43° 34.18	70° 01.84	M9
Southwest interception of clay clumps	43° 33.87	70° 02.34	R9
Southwest dense clay patch areas on approach to disposal site	43° 33.92	70° 02.33	
Southeast interception of clay clumps	43° 34.05	70° 01.70	R12
Southeast border	43° 33.94	70° 01.71	

advantages:

- o In operation as a free maneuvering sled in contact with flat homogeneous bottom substrate, the video and photographic records of both vehicles provided a standard format that permitted quantified estimates of species abundance.

- o The high resolution close-focus frame of reference of the ROV allowed identification and enumeration of small and cryptic species. Important deep water ecological results were obtained by statistical treatment of the submersible and ROV photographic data. A new perspective on the distribution and abundance patterns of small (1-3 cm) and motile epibenthic organisms has been obtained by video analysis, that would be undetectable by conventional sampling methods.

- o Proficient pilot control and precision navigation enabled detailed inspection of critical seafloor areas.

- o Due to turbid water creating visual restrictions at the substrate-water interface, the ROV observations produced high resolution near-field imagery to augment the greater range of submersible observation.

- o Operator manipulation of the sediment surface with the attached port and starboard calibration bars on the ROV indicated sediment cohesiveness, micro-scale topography and depth of nepheloid layer veneer characteristic of disposed material.

- o The submersible and ROV performed linear inspection transects with precision-navigation course control in reference to existing bathymetry charts to inspect contour changes, border regions, or benthic targets.

- o A smaller ROV 'sphere of influence' produced less avoidance behavior for certain species and allowed unique observations of faunal-substrate interactions.

Conclusions drawn from the data obtained at each of the three disposal sites are:

<u>Foul Area</u>

- o A near bottom turbidity zone of suspended particulate material exists to approximately 10 m above the substrate.

- Dense mysid and pandalid populations occur in the disposal site region. These species were highly interactive with the surficial nepheloid layer and were distributed vertically within a 20 cm height above the substrate. Pandalids exhibited strong thigmotaxis to mound/clump features. Mysids and pandalids are important prey and commercial fishery resources, respectively, in the region.

- A low degree of biotic erosion and disintegration of clay mounds had occurred in these deep, cold (approximately 4^{o} C bottom water) disposal sites. In contrast southern New England shallow water sites experience a greater rate of macrofaunal invasion and bioerosion effect on post-disposal sediment topography (Stewart, 1982).

- During this survey, no commercial fishing activity was noted on the surface or by search for active or ghost gear on the bottom.

- Distinct physical dredged material mound borders were detectable and within an approximately 300 - 400 m radius of the target buoy locations for both hopper and scow disposal methods. The vertical relief encountered on transects averaged 1 to 2 m with considerable areas on soft flat substrate between gray clay clumps.

- Brief reconnaissance of the suspected radioactive canister site produced evidence of several disintegrated 50 gallon steel drums but no cement encased containers were encountered.

- Moderate counts of flounder species (Pleuronectidae) were obtained.

- Highly aggregated patches of mud anenome (*Cerianthus borealis*) forests were encountered.

Cape Arundel Disposal Site

- Inspection of the south (historical) disposal site revealed extensive areas of prime hard rock substrate and burrowed dredged material conducive to important fishery habitat (i.e. lobster, hake, cod). The lateral exposed bedrock ridges (NW to SE orientation) had 3 to 5 m vertical relief and were bounded by a cobble base grading to sand-silt sediment.

- Fishing gear debris was encountered along the south site transects (i.e. gill net weights, trawl mesh, relict lobster pots, anchors).

- The attached bedrock substrate fauna was typical of the region.

- The north pre-designated site, considered for containment of dredged material and low fishery impact potential, was characterized as a sand depression (approx. 500 m in width) with lower habitat diversity than the south site.

<u>Portland Disposal Site</u>

- The extent of clay mound coverage at the site was considerably greater than predicted for target point disposal operations.

- Occurrence of angular clay mounds and numerous dock pilings produced spatially complex post-disposal mound features.

- Initial colonization of dredged material by macrofauna and megafauna appeared to be slow. Megafaunal colonization, sessile fauna settlement and bioerosion had occurred at greatly reduced rates when compared to disposal sites off southern New England.

- Adjacent hard rock substrate exhibited diverse attached fauna at dredged material mound borders. Density of attached organisms appeared more influenced by depth rather than proximity to the disposal site.

- Highly aggregated forests of mud anemones were observed. They are shown to enhance local species diversity and provide shelter for a variety of species.

- A juvenile cod burial behavior was documented at a reference station south of the disposal site. At an area with soft uncohesive surface sediments, individuals were observed buried to nearly the dorsal surface. Fish also occurred resting on the sediment surface and swimming in the near bottom water column.

6.0 REFERENCES

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APPENDIX VI

Representative Photographs
Obtained by Submersible and ROV Operations

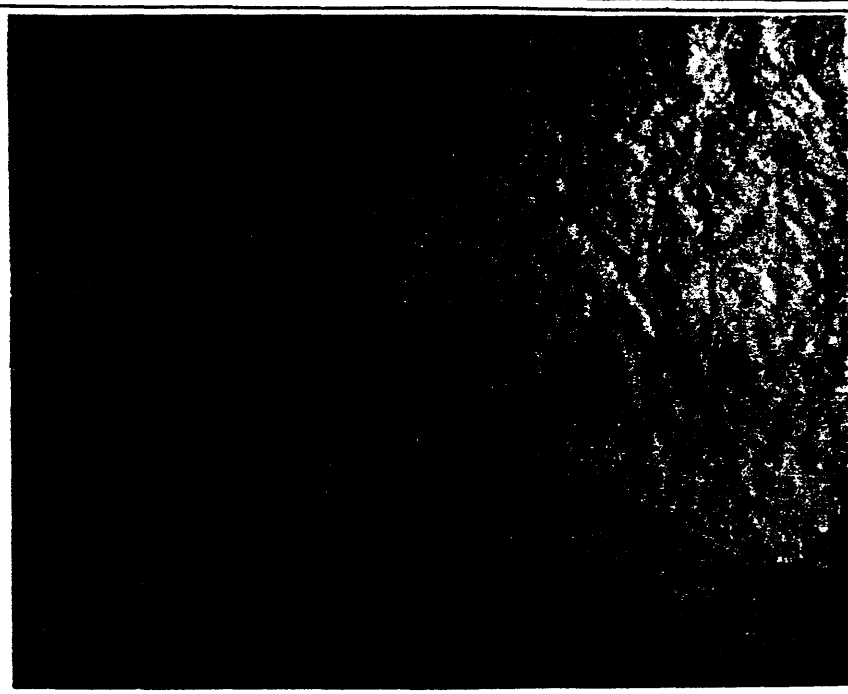

Plate 1. FA. Crustacean and finfish tracks on soft silt substrate. Tracks are caused by normal behavorial activities such as walking, fin winnowing of surface for camoflage, burst swimming, etc.

Plate 2. FA. Vertical burrow (40-50 mm dia.) in anemone field. The spatially complex areas attract high densities of megafauna from otherwise flat and featureless bottoms.

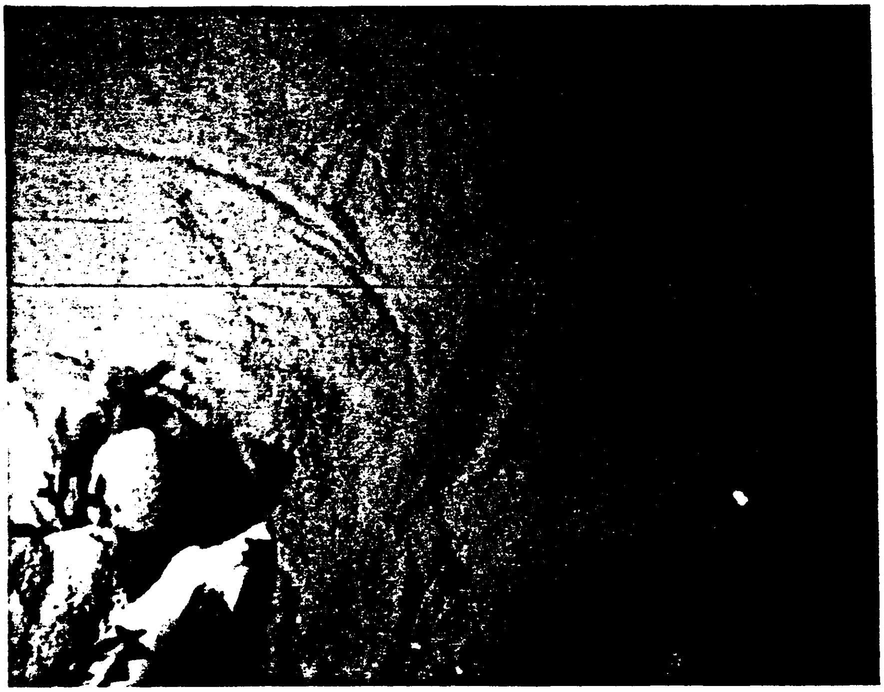

Plate 3. FA. Redfish, Sebastes marinums, exhibiting thigmotactic response to rock and sponges.

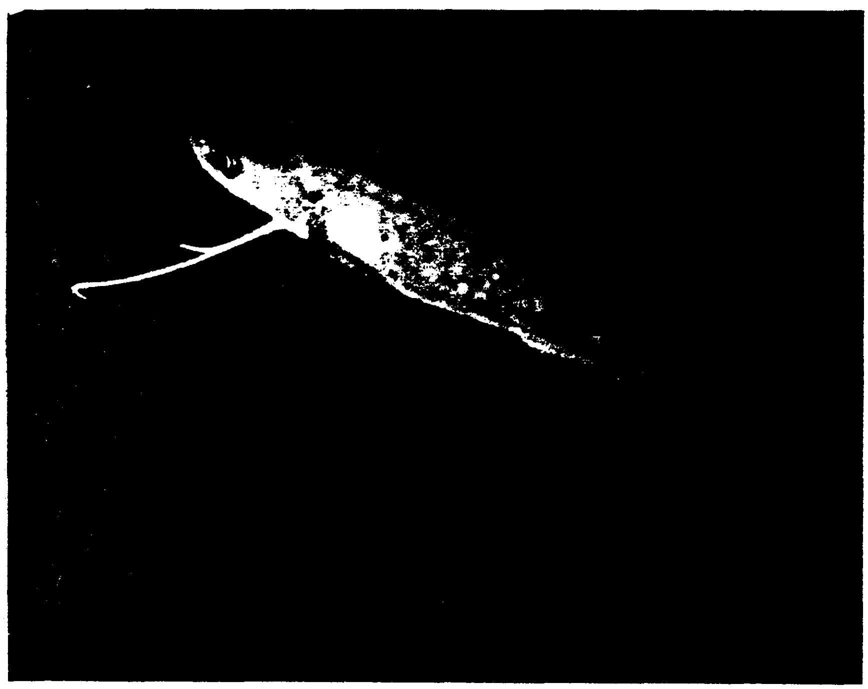

Plate 4. FA. Hake, Uorphycis tenuis, probing the surface for prey withmodified ventral fins.

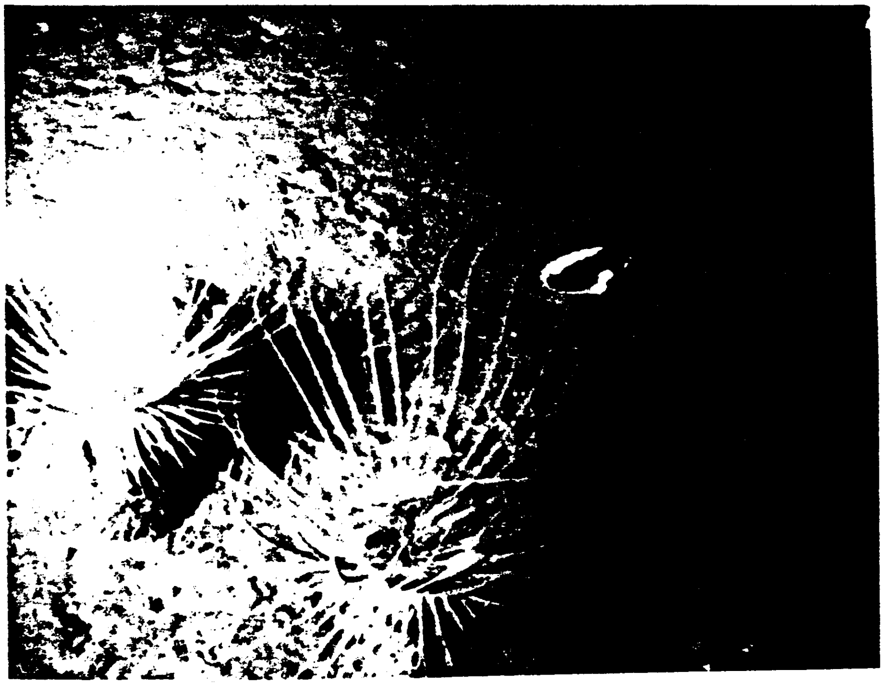

Plate 5. CADS South Site. Burrowing anemone field.

Plate 6. CADS South Site. Derelict fishing gear (cod and mesh) on the sand silt.

Plate 7. CADS South Site. Derelict line and anchor from previous fishing activity.

Plate 8. Portland. Lobster, Homarus americanus, burrow in dredged material. Increased spatial complexity created by disposal material attracts benthic megafauna like lobsters and hakes to these areas.

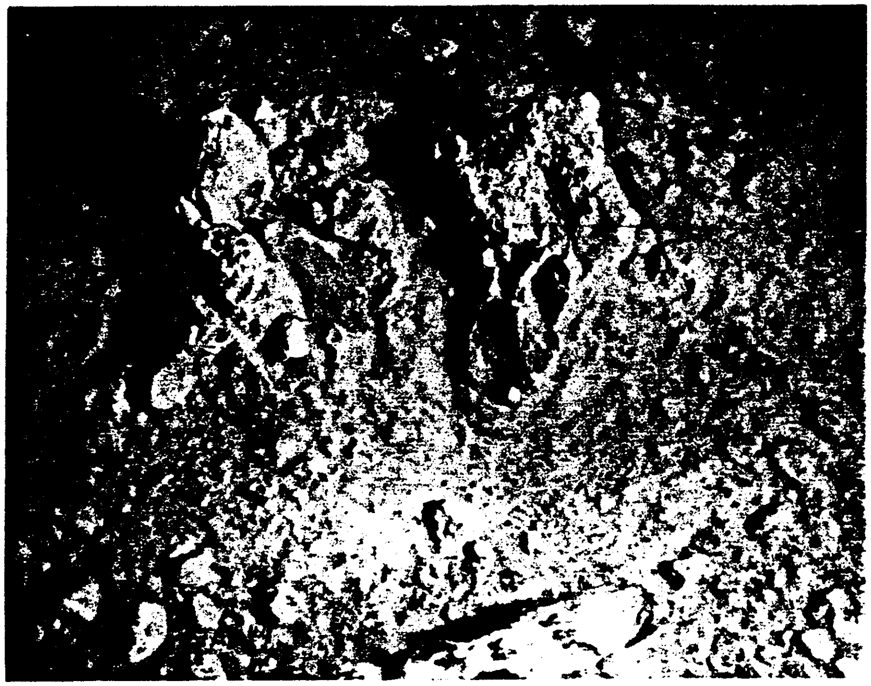

Plate 9. Portland. Angular, partially eroded clay clump. Bioerosion at these deepwater Gulf of Maine sites is much slower than at shallow southern New England sites.

Plate 10. Portland. Clay clump at a more advanced stage of erosion.

Plate 11. Portland. Eelpout, Macrozoarces americanus, on sediment surface. Note amphipod tubes and Polymastia sponge.

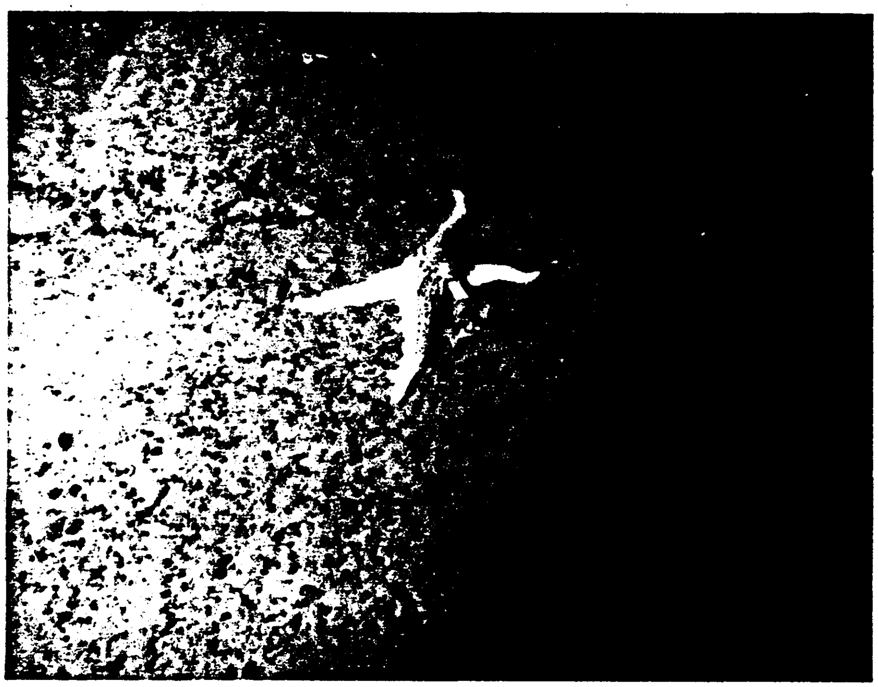

Plate 12. Portland. Starfish, Leptasteries sp., with a regenerate arm.

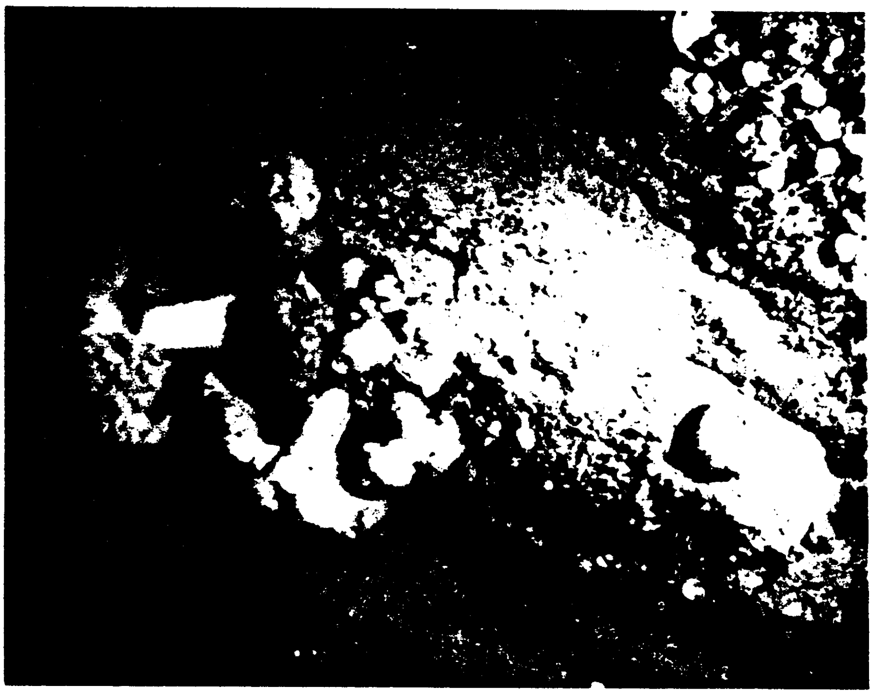

Plate 13. Portland. Typical hardrock substrate assemblage which occurs around the disposal site.

VII. GREEN HARBOR WAVE CLIMATE

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VII. GREEN HARBOR WAVE CLIMATE

1.0 INTRODUCTION AND METHODS

Between 15 June 1983 and 1 June 1984, the nearshore directional wave characteristics at Green Harbor, Massachusetts were measured. Four separate deployments of a Sea Data Corporation Directional Wave Gauge were made, the first three lasting approximately 60 days and the fourth lasting 100 days. For the first time period, 15 June 1983 to 14 August 1983, a Model 935-9 Directional Wave Gage was used, while the second, third and fourth deployments, 26 August to 27 October 1983, and 10 November to 14 December 1983, and 23 February to 1 June 1984 used a Model 635-12; both models are manufactured by Sea Data Corporation. Each model has burst sampling capabilities that permit measurement of waves as well as mean flows. During all three time periods, waves were sampled once every eight hours (three times a day) for seventeen minutes, acquiring a measurement of pressure and two horizontal velocity components once every half second for a total of 2048 samples per burst. Spectral estimates from these data were ensemble-averaged over 16 data subsets, yielding 32 degrees of freedom, with a frequency resolution of 0.0156 Hz. Confidence intervals of 95% for these spectra, with 32 degrees of freedom give an expected spectral estimate within 0.65 and 1.76 of the sample value.

In all cases, the instrument was deployed in the vicinity of buoy "1" at Green Harbor, Massachusetts (Fig. VII-1-1). The bottom within approximately 50 meters of the installation is flat, sandy, with medium sand grain size and widely scattered 1-2 feet high boulders. Attempts to fluidize the sediment in a 1" I.D. pipe and visual inspections indicated that the sand cover is about 6"-12" deep and overlies a cobbly bottom. Tables VII-1-1 through VII-1-4 contain instrument deployment summaries for each time period.

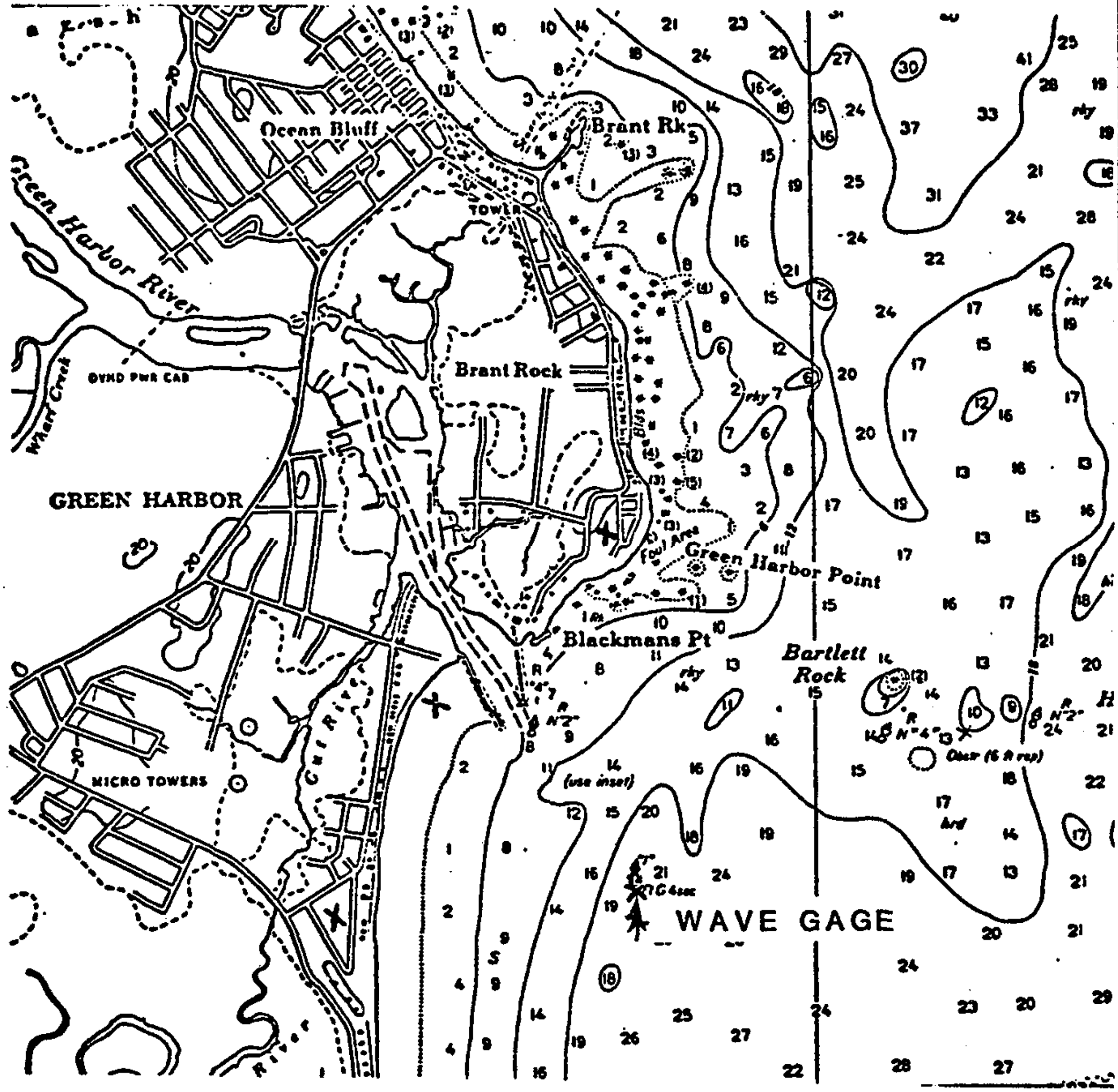
For each set of data, two parameters, variance (s^2) and significant wave height ($H_{1/3}$), were calculated to measure wave energy. Variance (s^2) is defined by:

$$E = \rho g \langle \eta^2 \rangle$$

where E is the total energy, is density of water, and g is the gravitational acceleration. Variance, therefore, is a direct function of the wave energy. Besides wave variance, the other parameter used to represent wave energy was the significant wave height, $H_{1/3}$, where:

$$H_{1/3} \approx 4\sqrt{\langle \eta^2 \rangle}$$

This wave height is close to the wave height one would estimate visually from a random wave field.



X = Location of shore navigation stations.

FIGURE VII-1-1. Green Harbor Wave Gage Location Map.

TABLE VII-1-1. Instrument Deployment Summary

Instrument Type:	Sea Data Corporation Directional Wave Gage Model 635-9
Location:	Green Harbor, MA; vicinity of Buoy "1"
Deployment Date:	15 June 1983
Retrieval Date:	26 August 1983
Data Start Date:	15 June 1983
Data End Date:	14 August 1983
Burst Sample Interval:	8 hours
Burst Duration:	1024 seconds
Burst Sample Rate:	0.5 seconds
Continuous Sample Rate:	(N/A)*
Internal Averaging:	Yes
Data Quality:	Excellent
Height of Pressure Sensor above Bottom:	1.48m
Height of Current Meter above Bottom:	2.06m
Orientation of Current Meter (Positive X axis is towards Direction from which + X flow is coming):	346.0°T.N.

Daily Measurement Times:

01:	0113 E.D.T.
02:	0913 E.D.T.
03:	1713 E.D.T.

*(N/A) - Not applicable in this instrument

TABLE VII-1-2

INSTRUMENT DEPLOYMENT SUMMARY

Instrument Type:	Sea Data Corporation Directional Wave Gage Model 635-12
Location:	Green Harbor, MA (Vicinity of Buoy "1")
Deployment Date:	26 August 1983
Retrieval Date:	27 October 1983
Data Start Date:	26 August 1983
Data End Date:	26 October 1983
Burst Sample Interval:	8 hours
Burst Duration:	1024 seconds
Burst Sample Rate:	0.5 seconds
Continuous Sample Rate:	7.5 minutes
Internal Averaging:	Yes
Data Quality:	Excellent
Height of Pressure Sensor above Bottom:	0.18 m
Height of Current Meter above Bottom:	1.98 m

Orientation of Current Meter: 94.25°TN
(Positive X axis is towards direction from which + X flow is coming)

Daily Measurement Times:

01: 0632 E.D.T.
02: 1432 E.D.T.
03: 2232 E.D.T.

TABLE VII-1-3

INSTRUMENT DEPLOYMENT SUMMARY

Instrument Type:	Sea Data Corporation Directional Wave Gage Model 635-12
	Green Harbor, MA (Vicinity of Buoy "1")
Deployment Date:	10 November 1983
Retrieval Date:	14 December 1983
Data Start Date:	10 November 1983
Data End Date:	14 December 1983
Burst Sample Interval:	8 hours
Burst Duration:	1024 seconds
Burst Sample Rate:	0.5 seconds
Continous Sample Rate:	7.5 minutes
Internal Averaging:	Yes
Data Quality:	Good*
Height of Pressure Sensor above Bottom:	0.17 m
Height of Current Meter above Bottom:	1.94 m

Orientation of Current Meter: 89.25° TN**
(Positive X axis is towards direction from which + X flow is coming)

Daily Measurement Times:

01: 0746 E.D.T.
02: 1546 E.D.T.
03: 2346 E.D.T.

* Apart from the directional estimate problem due to EMCM movement, the overall data quality is good.

** Original Orientation

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Table VII-1-4

INSTRUMENT DEPLOYMENT SUMMARY

Instrument Type:	Sea Data Corporation Directional Wave Gage Model 635-12		
Location:	Green Harbor, MA; vicinity of Buoy "1"		
Deployment Date:	23 February 1984;	Retrieval Date:	7 June 1984
Data Start Date:	23 February 1984;	Data End Date:	1 June 1984
Burst Sample Interval:	8 Hours	Burst Duration:	1024 seconds
Burst Sample Rate:	0.5 seconds	Continuous Sample Rate:	7.5 minutes
Internal Averaging:	Yes	Data Quality:	Excellent
Height of Pressure Sensor above Bottom:	0.15 m	Height of Current Meter above Bottom:	2.07 m (23 Feb-7 Mar) 1.72 m (7 Mar-1 June)

Orientation of Current Meter
(Positive X axis is towards
Direction from which + X flow is coming): 18.25° T.N. (23 Feb-7 Mar)
115.25° T.N. (7 Mar-7 June)

Daily Measurement Times:

01:	0055 E.S.T.
02:	0855 E.S.T.
03:	1655E.S.T.

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2.0 RESULTS

For the 15 June to 14 August measurement period, wave energy was very low, averaging only 25 cm^2 in variance, while the mean significant wave height was only 0.12m. The mean peak wave period was just over 10 seconds. Because the analysis was cut-off at 4.0 seconds due to depth limitations, periods less than this are not reported (Table VII-2-1). Variances calculated from pressure data did not agree as well as expected with those calculated from velocity data, although agreement is still acceptable. Since velocity information was primarily used only to establish wave direction, and secondarily for variance comparison and calculation of mean flow velocities, this is not a serious problem. Possible explanations for this situation are a noisy current meter probe or incorrect calibration of the probe.

Wave propagation for the most part was toward the west (260° TN) with an occasional shift toward the northwest or southwest during locally generated events. Mean current flow for the period was toward the northeast (030° TN) suggesting a clockwise general mean circulation in Cape Cod Bay (Table VII-2-1).

For the 26 August to 27 October measurement interval, wave energy averaged 120 cm^2 in variance and the mean significant wave height was 0.32m. The mean peak wave period was just under nine seconds (Table VII-2-2). In contrast to the previous measurement interval, variances in this data set, as calculated from pressure, agreed well with those calculated from velocity. However, this relationship was characterized by gradual degradation probably due to a fouling of the electromagnetic current meter (EMCM) ball over the period of deployment.

A new problem was encountered with reduction of the Model 635-12 Wave Gage data. Velocity variances (hence directional estimates) are questionable for a number of runs because of a difficulty in separating error records from velocity roll-overs, a problem peculiar to the 635-12 (this roll-over does not occur in the Model 635-9, the instrument used for the first two months of data acquisition).

Wave propagation for the most part was toward the west (260° TN) with an occasional shift toward the northwest or southwest during locally generated events. Mean current flow for the period was toward the northeast (050° TN) as it was in the previous measurement interval.

A storm on 24-25 October 1983 provided the highest energy levels of the first two measurement periods. Preceded by a fairly active period from 20 October to 23 October, this storm produced a peak significant wave height of 1.86 m and a peak total energy variance of 2160 cm^2 during the 25 October 1983, 1432 measurement. Wave propagation was 239° - 277° TN with wave periods of 7.1 - 12.8 seconds.

TABLE VII-2-1

Analysis of the 61 day wave/tide record, measured at Green Harbor, Massachusetts with a Sea Data 635-9. Values are recorded at 8 hour intervals for the following parameters:

$\bar{h}$	= mean water depth (m)
E_T	= total energy varience in wave (cm^2) This parameter is proportional to the amount of energy in the wave. Comparison values calculated from pressure and velocity are presented. Velocity calculated values are in parentheses.
$H_{1/3}$	= significant wave height (m) This parameter is derived directly from E_T. Where: $H_{1/3} \approx 4\sqrt{\langle\eta^2\rangle}$
Peak F	= peak wave frequency (sec^{-1})
Peak T	= peak wave period = $\frac{1}{\text{peak wave frequency}}$
α_o	= direction of wave propagation, measured in degrees clockwise from true north
$P(\alpha_o)$	= angular spread of direction of propagation of the wave field
E_p	= energy in peak frequency variance (cm^2)
$\bar{U},\bar{V}$	= components of current velocity (m/sec); U is positive to the north, V is positive to the east

Dashes in the wave data indicates absence of significant wave peaks at periods greater than 4 seconds.

RUN	h (m)	$E_T (cm^2)$		$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	$E_P (cm^2)$	U (m/sec)	(m/
15 June 83 - 03	10.13	1	(6)	.04	.0781	12.8	230	55	0.4	0.03	-0.12
16 June 83 - 01	9.81	2	(21)	.06	.0781	12.8	260	88	0.5	0.02	-0.06
- 02	7.88	0	(19)	.00	----	----	---	--	---	-0.07	-0.01
- 03	10.51	6	(45)	.10	.1094	9.1	259	45	2.1	-0.06	-0.05
17 June 83 - 01	9.00	4	(49)	.08	.1250	8.0	259	59	0.7	0.01	-0.02
- 02	8.58	1	(30)	.04	----	---	---	--	---	-0.11	-0.09
- 03	10.60	--	(39)	.25(vel)	.1094	9.1	258	57	9.5(vel)	0.03	0.00
18 June 83 - 01	8.30	2	(18)	.06	.1094	9.1	269	51	0.6	-0.02	0.05
- 02	9.12	2	(14)	.06	.1094	9.1	257	71	0.5	-0.06	-0.03
- 03	10.31	2	(20)	.06	.0938	10.7	232	47	0.7	0.05	0.01
19 June 83 - 01	8.03	0	(11)	.00	----	----	---	--	---	-0.01	-0.01
- 02	9.79	1	(9)	.04	.1094	9.1	273	68	0.4	-0.10	-0.03
- 03	9.75	2	(15)	.06	.1094	9.1	274	53	0.9	0.05	0.00
20 June 83 - 01	7.90	1	(18)	.04	.1094	9.1	278	76	0.4	-0.04	-0.04
- 02	10.26	3	(12)	.07	.0938	10.7	259	61	0.6	-0.02	-0.16
- 03	9.17	1	(17)	.04	.0781	12.8	264	44	0.2	-0.05	-0.06
21 June 83 - 01	8.27	1	(10)	.04	.1094	9.1	282	52	0.3	-0.15	-0.09
- 02	10.52	2	(12)	.06	.0781	12.8	236	79	0.4	-0.03	-0.17
- 03	8.69	1	(12)	.04	.0781	12.8	248	52	0.4	-0.05	-0.09
22 June 83 - 01	8.84	1	(5)	.04	.0781	12.8	270	47	0.3	-0.23	-0.07
- 02	10.33	3	(13)	.07	.0781	12.8	254	44	0.8	-0.08	-0.06
- 03	8.19	1	(5)	.04	.0938	10.7	260	73	0.1	-0.07	-0.05
23 June 83 - 01	9.45	1	(3)	.04	.0938	10.7	255	65	0.2	-0.18	-0.04
- 02	9.92	1	(5)	.04	.0938	10.7	252	53	0.3	0.00	-0.10
- 03	7.93	1	(4)	.04	.0938	10.7	292	56	0.2	-0.08	0.02
24 June 83 - 01	9.86	1	(4)	.04	.0938	10.7	268	53	0.3	-0.06	-0.08
- 02	9.39	1	(4)	.04	.0938	10.7	286	55	0.2	-0.04	-0.07
- 03	8.08	0	(5)	.00	----	----	---	--	---	-0.05	-0.02

RUN	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\tilde{U}$ (m/sec)	(m/
25 June 83 - 01	10.30	1 (6)	.04	.0781	12.8	213	72	0.4	-0.11	-0.06
- 02	9.01	1 (6)	.04	.0781	12.8	237	42	0.2	-0.01	-0.06
- 03	8.24	1 (15)	.04	.0781	12.8	298	66	0.2	-0.02	-0.04
26 June 83 - 01	10.70	2 (10)	.06	.0938	10.7	251	74	1.0	-0.12	-0.13
- 02	8.65	1 (9)	.04	.1094	9.1	286	63	0.4	-0.05	-0.07
- 03	8.83	0 (14)	.00	----	----	---	--	---	-0.09	-0.10
27 June 83 - 01	10.75	2 (16)	.06	.0938	10.7	223	81	0.9	0.01	-0.05
- 02	8.24	2 (17)	.06	.1094	9.1	260	44	1.2	-0.01	-0.01
- 03	8.96	1 (9)	.04	.0938	10.7	271	72	0.4	-0.08	-0.05
28 June 83 - 01	10.64	4 (24)	.08	.1094	9.1	205	77	1.3	-0.02	-0.11
- 02	8.07	1 (17)	.04	.1094	9.1	267	49	0.3	0.06	-0.03
- 03	9.34	3 (41)	.07	.1094	9.1	298	81	0.5	-0.08	-0.11
29 June 83 - 01	10.41	3 (21)	.07	.1250	8.0	244	65	0.5	0.06	-0.03
- 02	7.91	1 (8)	.04	.1094	9.1	275	72	0.2	-0.08	-0.02
- 03	9.71	2 (14)	.06	.1094	9.1	280	68	0.2	-0.05	-0.12
30 June 83 - 01	10.02	2 (8)	.06	.0781	12.8	268	55	0.8	0.00	0.05
- 02	7.93	1 (10)	.04	.0781	12.8	232	60	0.5	-0.03	0.01
- 03	9.97	6 (22)	.10	.0781	12.8	274	42	2.4	-0.05	-0.05
01 July 83 - 01	9.57	7 (34)	.11	.1094	9.1	270	45	2.3	-0.04	-0.02
- 02	8.09	3 (19)	.07	.0781	12.8	273	53	0.8	-0.01	-0.09
- 03	10.12	3 (24)	.07	.0781	12.8	242	65	0.7	-0.11	-0.06
02 July 83 - 01	9.12	4 (19)	.08	.1094	9.1	281	50	1.1	0.00	-0.02
- 02	8.41	3 (26)	.07	.1094	9.1	276	55	0.9	-0.02	-0.09
- 03	10.23	5 (17)	.09	.1094	9.1	276	57	1.3	-0.10	-0.06
03 July 83 - 01	8.79	4 (16)	.08	.1250	8.0	261	43	1.4	0.03	0.00
- 02	8.87	4 (15)	.08	.1250	8.0	282	56	1.1	-0.05	-0.17
- 03	10.27	6 (23)	.10	.1094	9.1	283	46	1.2	-0.05	-0.04
04 July 83 - 01	8.42	2 (9)	.06	.1094	9.1	289	38	0.4	-0.01	0.01
- 02	9.27	2 (11)	.06	.1094	9.1	285	65	0.6	-0.06	-0.07
- 03	10.04	3 (13)	.07	.1094	9.1	245	46	0.6	-0.03	-0.03

RUN	h (m)	$E_T(cm^2)$		$H_{1/3}$(m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	$E_P(cm^2)$	" (m/sec)	(m/
05 July 83 - 01	8.12	1	(4)	.04	.0938	10.7	271	32	0.4	-0.11	-0.04
- 02	9.68	2	(7)	.06	.0625	16.0	260	60	0.5	-0.01	-0.09
- 03	9.68	2	(5)	.06	.0938	10.7	286	42	0.6	-0.10	-0.03
06 July 83 - 01	8.06	1	(4)	.04	.0625	16.0	261	54	0.5	-0.02	-0.14
- 02	10.07	2	(4)	.06	.0625	16.0	262	47	1.2	0.01	-0.17
- 03	9.34	2	(5)	.06	.0625	16.0	260	49	0.6	-0.07	-0.02
07 July 83 - 01	8.33	2	(11)	.06	.0625	16.0	292	54	1.0	-0.06	-0.09
- 02	10.32	41	(124)	.26	.1875	5.3	248	51	11.	-0.07	-0.01
- 03	8.89	12	(38)	.14	.1094	9.1	288	41	2.0	0.03	-0.03
08 July 83 - 01	8.73	7	(20)	.11	.1094	9.1	264	63	1.6	-0.08	-0.03
- 02	10.32	12	(21)	.14	.1094	9.1	281	33	3.1	0.06	-0.01
- 03	8.29	6	(15)	.10	.1094	9.1	276	42	3.5	0.06	0.03
09 July 83 - 01	9.33	3	(8)	.07	.0781	12.8	278	36	1.0	-0.14	-0.04
- 02	10.03	4	(10)	.08	.1094	9.1	267	67	1.0	0.01	-0.01
- 03	7.81	2	(6)	.06	.0781	12.8	268	46	0.4	-0.03	-0.03
10 July 83 - 01	10.11	6	(23)	.10	.0781	12.8	262	46	1.3	-0.02	-0.09
- 02	9.55	6	(27)	.10	.2500	4.0	237	58	1.3	-0.04	-0.12
- 03	7.69	2	(10)	.06	.0781	12.8	284	70	0.4	-0.06	-0.04
11 July 83 - 01	10.74	2	(6)	.06	.0781	12.8	193	79	0.5	-0.08	-0.04
- 02	8.84	1	(4)	.04	.0781	12.8	261	54	0.2	0.02	0.03
- 03	7.98	2	(4)	.06	.0781	12.8	275	45	0.6	-0.11	-0.04
12 July 83 - 01	11.21	4	(10)	.08	.0938	10.7	223	62	1.1	-0.05	-0.02
- 02	8.19	5	(13)	.09	.1094	9.1	273	51	1.5	-0.02	-0.01
- 03	8.68	4	(9)	.08	.1094	9.1	275	45	1.4	-0.04	-0.13
13 July 83 - 01	11.23	16	(31)	.16	.0781	12.8	230	62	8.8	-0.04	-0.02
- 02	7.52	48	(83)	.28	.1094	9.1	284	31	30.	-0.01	0.05
- 03	9.39	18	(31)	.17	.0938	10.7	277	32	4.9	0.06	-0.09

RUN	h (m)	E_T (cm^2)		$H_{1/3}$ (m)	Peak F (sec^{-1})	k T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	(m/
14 July 83 - 01	10.75	17	(28)	.16	.1094	9.1	252	48	3.6	-0.06	-0.04
- 02	7.39	8	(14)	.11	.1094	9.1	280	31	3.2	-0.02	-0.03
- 03	10.11	9	(25)	.12	.1094	9.1	242	49	1.9	-0.01	-0.07
15 July 83 - 01	9.96	5	(10)	.09	.1094	9.1	283	35	1.8	-0.02	-0.02
- 02	7.58	2	(7)	.06	.1094	9.1	270	53	0.8	-0.02	-0.06
- 03	10.58	5	(8)	.09	.1094	9.1	242	46	1.4	0.02	-0.12
16 July 83 - 01	9.13	4	(7)	.08	.1094	9.1	260	21	1.0	-0.06	-0.02
- 02	8.20	2	(5)	.06	----	---	(BROAD)	--	---	-0.04	-0.09
- 03	10.82	6	(11)	.10	.1094	9.1	213	65	1.3	-0.02	-0.02
17 July 83 - 01	8.48	2	(4)	.06	.1250	8.0	252	51	0.3	-0.01	0.02
- 02	8.97	2	(6)	.06	.0938	10.7	271	45	0.4	0.02	-0.05
- 03	10.60	6	(12)	.10	.1250	8.0	239	42	1.1	-0.04	0.02
18 July 83 - 01	7.99	6	(11)	.10	.1094	9.1	279	33	2.1	-0.06	0.02
- 02	9.58	4	(8)	.08	.1094	9.1	278	32	1.6	-0.03	-0.08
- 03	10.10	5	(8)	.09	.1094	9.1	280	47	1.6	-0.10	-0.02
19 July 83 - 01	7.87	4	(11)	.08	.1094	9.1	285	45	2.2	-0.03	-0.02
- 02	10.07	5	(9)	.09	.1094	9.1	241	39	1.1	-0.01	-0.14
- 03	9.56	4	(7)	.08	.1094	9.1	280	37	1.2	-0.01	-0.01
20 July 83 - 01	8.13	3	(5)	.07	.1094	9.1	287	44	1.0	-0.13	-0.04
- 02	10.37	4	(8)	.08	.1094	9.1	214	53	0.7	-0.07	-0.08
- 03	9.02	3	(7)	.07	.1094	9.1	267	36	0.5	-0.02	0.01
21 July 83 - 01	8.64	2	(5)	.06	.1094	9.1	273	60	0.5	-0.10	-0.07
- 02	10.28	6	(12)	.10	.0938	10.7	256	43	1.2	0.00	-0.07
- 03	8.47		(9)	.12(vel)	.1250	8.0	270	41	1.2(vel)	-0.07	0.01
22 July 83 - 01	9.16	2	(7)	.06	.1094	9.1	277	49	0.5	-0.02	-0.06
- 02	10.07	5	(15)	.09	.0938	10.7	244	56	0.7	0.02	-0.02
- 03	8.28	65	(124)	.32	.1406	7.1	258	35	21.	-0.05	-0.01
23 July 83 - 01	9.75	110	(176)	.42	.1406	7.1	253	29	40.	-0.02	-0.05
- 02	9.71	187	(211)	.35	.1250	8.0	240	24	37.	0.03	-0.03
- 03	8.12	39	(57)	.25	.1406	7.1	261	26	12.	0.01	0.01

RUN	(m)	E_T(cm²)		$H_{1/3}$(m)	Peak F (sec⁻¹)	k T)	α_o	$P(\alpha_o)$	E_P(cm²)	(m/sec)	(m/s
24 July 83 - 01	10.17	19	(28)	.17	.0938	10.7	284	45	2.8	-0.08	-0.06
- 02	9.26	11	(12)	.13	.0938	10.7	281	26	2.8	0.02	0.02
- 03	8.21	7	(14)	.11	.0938	10.7	282	43	2.3	-0.06	-0.06
25 July 83 - 01	10.60	13	(18)	.14	.0938	10.7	247	61	3.9	-0.11	-0.10
- 02	8.95	124	(145)	.43	.1875	5.3	244	30	33.	-0.05	0.02
- 03	8.47	22	(47)	.19	.2031	4.9	252	65	4.4	-0.03	-0.04
26 July 83 - 01	10.78	34	(47)	.23	.1875	5.3	248	43	5.5	-0.07	-0.07
- 02	8.57	11	(15)	.13	.1094	9.1	275	22	2.4	0.00	0.04
- 03	8.77	31	(47)	.22	.1250	8.0	265	46	8.2	-0.04	-0.07
27 July 83 - 01	10.78	98	(111)	.40	.1250	8.0	265	34	3.6	-0.12	-0.07
- 02	8.32	20	(24)	.18	.1250	8.0	272	21	7.0	0.00	0.00
- 03	9.12	23	(29)	.19	.1250	8.0	281	31	6.0	-0.03	-0.07
28 July 83 - 01	10.65	17	(19)	.16	.0781	12.8	257	39	4.6	-0.12	-0.06
- 02	8.09	6	(8)	.10	.1094	9.1	276	24	1.7	0.02	0.03
- 03	9.44	11	(12)	.13	.0781	12.8	281	48	3.5	-0.05	-0.17
29 July 83 - 01	10.25	10	(11)	.13	.0781	12.8	279	34	3.6	-0.11	-0.05
- 02	7.87	7	(9)	.11	.1094	9.1	285	20	2.9	0.02	-0.02
- 03	9.75	4	(6)	.08	.0781	12.8	253	35	0.8	-0.08	-0.06
30 July 83 - 01	9.83	6	(9)	.10	.1094	9.1	274	42	1.5	0.03	-0.06
- 02	7.88	4	(6)	.08	.0938	10.7	268	32	1.3	-0.03	0.00
- 03	10.02	6	(9)	.10	.1094	9.1	278	42	1.1	-0.03	-0.03
31 July 83 - 01	9.39	6	(8)	.10	.0781	12.8	271	32	2.2	0.02	0.02
- 02	8.15	5	(8)	.09	.0781	12.8	277	32	1.4	-0.05	-0.06
- 03	10.33	13	(23)	.14	.0781	12.8	251	49	2.9	0.00	-0.09

TABLE VII-2-1 (Cont.)

RUN	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	k T c)	α_o	$P(\alpha_o)$	E_P (cm^2)	(m/sec)	(m/s
01 Aug. 83 - 01	9.06	6 (9)	.10	.1094	9.1	285	36	0.9	-0.07	-0.01
- 02	8.50	6 (11)	.10	.0781	12.8	268	44	1.3	-0.04	-0.03
- 03	10.48	8 (11)	.11	.1094	9.1	267	65	1.4	-0.10	-0.05
02 Aug. 83 - 01	8.61	5 (7)	.09	.0781	12.8	271	26	1.2	-0.05	-0.07
- 02	8.84	3 (4)	.07	.0938	10.7	279	29	1.3	-0.03	-0.06
- 03	10.34	5 (6)	.09	.0938	10.7	262	43	1.3	-0.09	-0.04
03 Aug. 83 - 01	8.19	2 (3)	.06	.1094	9.1	287	28	0.7	0.01	-0.01
- 02	9.41	2 (2)	.06	.1094	9.1	278	38	0.4	-0.01	-0.15
- 03	10.14	4 (4)	.08	.0781	12.8	246	41	0.7	-0.01	0.00
04 Aug. 83 - 01	7.97	2 (2)	.06	.1094	9.1	293	35	0.4	-0.06	-0.02
- 02	9.84	3 (3)	.07	.0781	12.8	235	40	0.5	-0.04	0.00
- 03	9.72	3 (5)	.07	.0781	12.8	274	37	0.6	-0.01	-0.05
05 Aug. 83 - 01	8.03	2 (3)	.06	.0781	12.8	281	34	0.6	-0.04	-0.02
- 02	10.28	4 (4)	.08	.0938	10.7	250	47	1.4	-0.03	-0.08
- 03	9.26	2 (2)	.06	.0938	10.7	285	38	0.7	-0.07	-0.01
06 Aug. 83 - 01	8.43	1 (3)	.04	.0938	10.7	266	60	0.3	-0.01	-0.09
- 02	10.43	2 (5)	.06	.0938	10.7	229	56	0.5	-0.01	-0.08
- 03	8.56	1 (2)	.04	.1094	9.1	264	49	0.2	0.01	0.01
07 Aug. 83 - 01	9.08	2 (7)	.06	.1094	9.1	281	57	0.7	-0.06	-0.05
- 02	10.29	3 (7)	.07	.0938	10.7	215	58	0.7	0.02	-0.03
- 03	7.89	2 (6)	.06	.0938	10.7	285	76	0.5	-0.02	-0.01
08 Aug. 83 - 01	9.85	2 (5)	.06	.0938	10.7	267	53	0.5	-0.08	-0.03
- 02	9.78	2 (8)	.06	.0938	10.7	257	67	0.3	-0.02	-0.02
- 03	7.55	1 (4)	.04	.0938	10.7	275	67	0.2	-0.04	-0.07
09 Aug. 83 - 01	10.56	4 (4)	.08	.0938	10.7	259	44	1.2	-0.07	-0.05
- 02	9.14	2 (4)	.06	.0781	12.8	275	39	0.5	0.01	0.01
- 03	7.74	1 (3)	.04	.0781	12.8	277	44	0.4	-0.02	-0.02
10 Aug. 83 - 01	11.23	4 (9)	.08	.0781	12.8	252	67	1.3	-0.06	-0.04
- 02	8.46	17 (45)	.16	.2031	4.9	252	63	3.4	0.00	0.06
- 03	8.37	7 (12)	.11	.0781	12.8	259	45	1.3	-0.10	-0.03

RUN		h (m)	$E_T(cm^2)$		$H_{1/3}$(m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	$E_P(cm^2)$	U (m/sec)	(m/sec)
11 Aug. 83	- 01	11.30	11	(17)	.13	.0781	12.8	237	56	3.5	-0.02	-0.05
	- 02	7.89	1	(4)	.04	.0781	12.8	272	47	0.4	-0.01	0.00
	- 03	9.18	18	(67)	.17	.2500	4.0	290	79	8.9	-0.04	-0.14
12 Aug. 83	- 01	10.89	193	(386)	.56	.2188	4.9	300	46	66.	0.04	0.00
	- 02	7.60	39	(96)	.25	.1406	7.1	260	58	7.3	-0.04	0.00
	- 03	10.13	836	(1471)	1.16	.1094	9.1	247	50	261.	0.01	-0.03
13 Aug. 83	- 01	10.26	1209	(1669)	1.39	.1094	9.1	252	40	227.	0.04	0.02
	- 02	7.72	189	(356)	.55	.1250	8.0	265	50	44.	0.04	0.03
	- 03	10.63	304	(488)	.70	.1250	8.0	265	41	61.	-0.05	-0.05
14 Aug. 83	- 01	9.41	171	(288)	.52	.1094	9.1	278	50	36.	0.03	0.01
	- 02	8.07	49	(84)	.28	.1094	9.1	284	44	14.	-0.09	-0.06
	- 03	10.86	59	(84)	.31	.1250	8.0	262	49	11.	-0.07	-0.02
MEAN		9.27	25	(45)							-0.04	-0.04
S.D.		1.00	115	(173)							0.05	0.05

TABLE VII-2-2

Analysis of the 63 day wave/tide record, measured at Green Harbor, Massachusetts with a Sea Data 635-12 Values are recorded at 8 hour intervals for the following parameters:

$\bar{h}$	= mean water depth (m)
$E_T(<\eta^2>)$	= total energy varience in wave (cm^2) This parameter is proportional to the amount of energy in the wave. Comparison values calculated from pressure and velocity are presented. Velocity calculated values are in parentheses.
$H_{1/3}$	= significant wave height (m) This parameter is derived directly from E_T. Where: $H_{1/3} = 4\sqrt{<\eta^2>}$
Peak F	= peak wave frequency (sec^{-1})
Peak T	= peak wave period = $\frac{1}{\text{peak wave frequency}}$
α_o	= direction of wave propagation, measured in degrees clockwise from true north
$P(\alpha_o)$	= angular spread of direction of propagation of the wave field
E_p	= energy in peak frequency variance (cm^2)
$\bar{U},\bar{V}$	= components of current velocity (m/sec); U is positive to the north, V is positive to the east

Dashes in the wave data indicates absence of significant wave peaks at periods greater than 4 seconds.

* Indicates bad data or questionable data in that particular field.
** Indicates entire record is bad.

SAIC

WAVE CLIMATE SUMMARY - GREEN HARBOR, MA 26 AUGUST 1983 - 27 OCTOBER 1983 SEA DATA 635-12

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
26 Aug 83	1432	10.05	6. (73.)*	0.10	0.1094	9.1	280.	72.	1.	0.02*	0.05*
	2232	8.45	6. (7.)	0.10	0.1250	8.0	267.	34.	1.	-0.01	0.00
27 Aug 83	632	8.22	5. (5.)	0.09	0.1094	9.1	278.	40.	2.	0.00	0.07
	1432	10.11	6. (11.)	0.10	0.1094	9.1	274.	44.	1.	-0.04	-0.01
	2232	8.12	5. (6.)	0.09	0.1250	8.0	268.	35.	1.	-0.01	-0.07
28 Aug 83	632	8.64	11. (9.)	0.13	0.1094	9.1	266.	39.	2.	0.00	0.07
	1432	10.05	12. (17.)	0.14	0.1250	8.0	261.	50.	5.	0.03	-0.04
	2232	7.85	5. (6.)	0.09	0.1250	8.0	274.	33.	1.	-0.02	-0.02
29 Aug 83	632	8.99	7. (43.)	0.11	0.1250	8.0	269.	39.	1.	-0.02	0.02
	1432	9.85	8. (15.)	0.12	0.2500	4.0	230.	53.	2.	0.03	-0.04
	2232	7.66	12. (14.)	0.14	0.2500	4.0	221.	29.	4.	-0.01	-0.06
30 Aug 83	632	9.38	28. (28.)*	0.21	0.2500	4.0	213.	32.	9.	-0.02	0.05*
	1432	9.47	27. (29.)	0.21	0.2500	4.0	238.	42.	7.	-0.05	0.01
	2232	7.69	12. (14.)	0.14	0.2344	4.3	237.	28.	3.	0.01	0.07
31 Aug 83	632	9.67	18. (22.)	0.17	0.1406	7.1	258.	36.	3.	-0.03	0.00
	1432	9.02	32. (34.)	0.23	0.1563	6.4	259.	27.	6.	0.01	0.08
	2232	7.94	64. (68.)	0.32	0.1094	9.1	270.	24.	20.	-0.13	-0.01
01 Sep 83	632	9.88	173. (192.)	0.53	0.1094	9.1	268.	28.	51.	-0.03	0.01
	1432	8.55	121. (121.)*	0.44	0.0938	10.7	265.	32.	38.	-0.02	-0.13*
	2232	8.48	80. (87.)	0.36	0.0938	10.7	269.	22.	39.	-0.02	0.02
02 Sep 83	632	9.77	96. (106.)	0.39	0.0938	10.7	272.	33.	36.	0.03	0.07
	1432	8.04	47. (44.)	0.27	0.1094	9.1	262.	36.	22.	-0.01	-0.10
	2232	9.07	33. (37.)	0.23	0.0938	10.7	261.	26.	14.	-0.05	0.02
03 Sep 83	632	9.33	31. (34.)	0.22	0.0938	10.7	263.	33.	10.	0.02	0.05
	1432	7.60	18. (22.)	0.17	0.0938	10.7	271.	33.	7.	-0.03	0.00
	2232	9.87	21. (25.)*	0.18	0.0938	10.7	268.	53.	6.	-0.02	0.05*
04 Sep 83	632	8.79	10. (11.)	0.13	0.0938	10.7	264.	43.	3.	0.01	0.01
	1432	7.55	10. (12.)	0.13	0.0781	12.8	257.	26.	5.	-0.02	0.01
	2232	10.43	23. (26.)*	0.19	0.0781	12.8	260.	63.	7.	-0.02*	1.32*

DATE	TIME	$\bar{h}$ (m)	$E_T(cm^2)$	$H_{1/3}$(m)	Peak f (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	$E_P(cm^2)$	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
05 Sep 83	632	8.11	16. (19.)	0.16	0.0781	12.8	270.	28.	6.	0.01	-0.01
	1432	7.98	13. (56.)	0.14	0.0938	10.7	265.	61.	4.	-0.06	0.08
	2232	10.75	12. (19.)	0.14	0.0781	12.8	314.	59.	3.	-0.03	0.07
06 Sep 83	632	7.48	13. (16.)	0.14	0.1094	9.1	280.	30.	4.	0.03	-0.01
	** 1432	8.71	12. (1.)	0.14	0.0781	12.8	413.	2.	4.	-0.10	0.05**
	2232	10.57	11. (12.)	0.13	0.0781	12.8	303.	54.	3.	0.03	0.06
07 Sep 83	632	6.98	11. (15.)	0.14	0.1094	9.1	280.	35.	4.	-0.03	-0.02
	1432	9.43	6. (10.)	0.10	0.0938	10.7	256.	33.	2.	-0.06	0.01
	2232	9.96	6. (11.)	0.10	0.0938	10.7	278.	67.	2.	-0.02	0.02
08 Sep 83	632	6.88	6. (8.)	0.10	0.0781	12.8	272.	27.	2.	-0.03	-0.02
	1432	10.10	6. (8.)	0.10	0.0938	10.7	271.	38.	2.	-0.02	0.08
	2232	9.16	6. (9.)	0.10	0.0938	10.7	266.	48.	1.	0.07	-0.01
09 Sep 83	632	7.23	3. (5.)	0.07	0.1094	9.1	278.	36.	1.	-0.04	0.06
	1432	10.52	5. (6.)	0.09	0.1094	9.1	231.	66.	1.	0.00	0.06
	2232	8.26	2. (4.)	0.06	0.0938	10.7	257.	38.	1.	-0.02	0.05
10 Sep 83	632	7.84	2. (4.)	0.05	0.1094	9.1	271.	32.	1.	-0.03	0.06
	1432	10.54	3. (7.)	0.07	0.1094	9.1	282.	52.	1.	-0.03	0.02
	2232	7.74	6. (7.)	0.09	0.2344	4.3	284.	49.	2.	0.01	-0.04
11 Sep 83	632	8.72	3. (6.)	0.07	0.0625	16.0	269.	45.	1.	-0.05	0.05
	1432	10.36	6. (10.)	0.10	0.2500	4.0	272.	72.	1.	0.01	0.05
	2232	7.31	3. (5.)	0.07	0.0625	16.0	276.	34.	1.	-0.03	-0.05
12 Sep 83	632	9.26	3. (5.)	0.07	0.0781	12.8	261.	34.	1.	-0.08	0.02
	1432	9.79	7. (7.)*	0.11	0.0781	12.8	271.	83.	1.	0.06*	0.00*
	2232	7.35	3. (3.)	0.07	0.0781	12.8	280.	40.	1.	0.02	0.09
13 Sep 83	632	9.70	3. (6.)	0.07	0.0781	12.8	278.	48.	1.	-0.04	0.01
	1432	9.23	79. (81.)	0.36	0.2031	4.9	234.	25.	23.	-0.03	0.04
	2232	7.78	18. (26.)	0.17	0.2031	4.9	256.	37.	5.	-0.06	0.04

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak f (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
14 Sep 83	632	9.97	440. (654.)	0.84	0.1875	5.3	240.	28.	115.	-0.02	0.06
	1432	8.77	274. (281.)	0.66	0.1719	5.8	245.	25.	81.	0.01	-0.03
	2232	8.42	138. (155.)	0.47	0.1563	6.4	252.	19.	30.	-0.01	0.05
15 Sep 83	632	9.93	202. (209.)	0.57	0.2031	4.9	252.	31.	50.	-0.02	-0.04
	1432	8.36	145. (152.)	0.48	0.1719	5.8	237.	23.	50.	-0.02	-0.03
	2232	9.03	33. (36.)	0.23	0.1563	6.4	265.	28.	7.	-0.02	0.09
16 Sep 83	632	9.58	50. (127.)	0.28	0.0938	10.7	280.	24.	8.	0.00	-0.03
	1432	8.04	27. (29.)	0.21	0.1094	9.1	264.	23.	7.	-0.02	0.00
	2232	9.51	67. (75.)	0.33	0.2500	4.0	294.	40.	21.	-0.02	0.08
17 Sep 83	632	9.06	131. (135.)	0.46	0.2500	4.0	252.	32.	33.	-0.01	0.01
	1432	7.99	75. (111.)*	0.35	0.1563	6.4	270.	24.	13.	0.00*	0.02*
	2232	9.92	94. (99.)	0.39	0.1094	9.1	266.	35.	16.	-0.02	0.04
18 Sep 83	632	8.60	72. (71.)	0.34	0.1406	7.1	264.	26.	10.	-0.01	-0.01
	1432	8.14	56. (56.)	0.30	0.1094	9.1	278.	22.	15.	-0.05	0.05
	2232	10.11	54. (124.)*	0.29	0.1406	7.1	262.	39.	11.	0.01*	1.05*
19 Sep 83	632	8.21	45. (45.)	0.27	0.1250	8.0	273.	32.	14.	0.00	-0.02
	1432	8.46	20. (23.)	0.18	0.1250	8.0	264.	27.	6.	-0.06	0.03
	2232	10.15	23. (27.)	0.19	0.1250	8.0	249.	32.	5.	-0.03	-0.06
20 Sep 83	632	7.88	23. (23.)	0.19	0.1250	8.0	273.	28.	7.	0.00	-0.04
	1432	8.79	20. (19.)	0.18	0.0938	10.7	270.	34.	5.	0.00	0.00
	2232	10.05	55. (61.)	0.30	0.0938	10.7	259.	47.	15.	0.05	0.02
21 Sep 83	632	7.62	75. (64.)	0.35	0.1094	9.1	259.	36.	46.	0.01	-0.06
	1432	9.12	22. (23.)	0.19	0.0938	10.7	260.	27.	8.	-0.03	0.03
	2232	9.83	65. (58.)	0.32	0.0938	10.7	267.	37.	24.	-0.02	-0.02
22 Sep 83	632	7.48	43. (108.)*	0.26	0.0938	10.7	263.	30.	9.	-0.01*	0.81*
	1432	9.47	40. (37.)	0.25	0.0938	10.7	268.	25.	21.	-0.03	0.02
	2232	9.51	39. (158.)*	0.25	0.0938	10.7	265.	33.	11.	-0.05*	2.25*

DATE	TIME	$\tilde{h}$ (m)	E_T(cm²)	$H_{1/3}$(m)	Peak [illegible] (sec⁻¹)	Peak T (sec)	α_o	$P(\alpha_o)$	E_P(cm²)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
23 Sep 83	632	7.48	37. (33.)	0.24	0.1094	9.1	271.	26.	14.	-0.02	0.05
	1432	9.80	33. (34.)	0.23	0.0938	10.7	271.	29.	10.	0.01	0.04
	2232	9.16	25. (25.)	0.20	0.1094	9.1	270.	33.	7.	0.03	-0.01
24 Sep 83	632	7.69	14. (12.)	0.15	0.0938	10.7	256.	51.	4.	0.01	0.06
	1432	10.12	13. (76.)	0.14	0.1250	8.0	245.	61.	2.	-0.06	0.00
	2232	8.73	29. (29.)	0.22	0.2344	4.3	225.	38.	8.	0.00	0.06
25 Sep 83	632	7.97	10. (8.)	0.12	0.0938	10.7	270.	38.	3.	-0.01	0.07
	1432	10.34	23. (25.)	0.19	0.0781	12.8	261.	43.	7.	-0.06	0.04
	2232	8.30	33. (26.)	0.23	0.0938	10.7	266.	28.	13.	0.00	0.00
26 Sep 83	632	8.28	26. (19.)	0.20	0.0781	12.8	273.	31.	11.	-0.04	0.07
	1432	10.34	30. (27.)	0.22	0.0938	10.7	269.	34.	11.	-0.03	-0.01
	2232	7.88	34. (27.)	0.23	0.0781	12.8	265.	36.	11.	-0.01	0.02
27 Sep 83	632	8.70	33. (26.)	0.23	0.0781	12.8	267.	35.	16.	-0.02	0.03
	1432	10.18	38. (101.)*	0.25	0.0938	10.7	271.	45.	14.	-0.01*	-0.05*
	2232	7.63	43. (118.)*	0.26	0.0781	12.8	264.	39.	19.	0.00*	0.30*
28 Sep 83	632	9.21	137. (122.)	0.47	0.2188	4.6	223.	31.	31.	-0.01	0.01
	1432	9.89	273. (221.)	0.66	0.1563	6.4	238.	28.	66.	-0.04	-0.03
	2232	7.57	70. (57.)	0.33	0.1719	5.8	258.	31.	12.	-0.02	0.01
29 Sep 83	632	9.65	85. (126.)*	0.37	0.2500	4.0	254.	35.	12.	0.00*	0.02*
	1432	9.40	59. (47.)	0.31	0.2344	4.3	253.	35.	13.	-0.01	-0.03
	2232	7.72	19. (15.)	0.17	0.1094	9.1	281.	35.	3.	-0.01	0.03
30 Sep 83	632	9.76	23. (17.)	0.19	0.0781	12.8	258.	44.	3.	0.00	0.03
	1432	8.79	17. (13.)	0.16	0.1875	5.3	251.	35.	2.	-0.01	-0.03
	2232	8.31	9. (8.)	0.12	0.0938	10.7	264.	40.	3.	-0.02	0.04
01 Oct 83	632	10.03	11. (10.)	0.13	0.0938	10.7	267.	66.	2.	0.00	0.05
	1432	8.22	6. (5.)	0.10	0.1094	9.1	260.	43.	1.	-0.01	-0.03
	2232	8.99	5. (5.)	0.09	0.1094	9.1	264.	44.	1.	-0.02	0.08

TABLE VII-2-2 (Cont.)

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak f (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
02 Oct 83	632	9.65	9. (6.)	0.12	0.0938	10.7	268.	42.	2.	0.00	-0.02
	1432	7.65	9. (37.)*	0.12	0.1094	9.1	257.	50.	2.	0.00*	-0.03*
	2232	9.70	14. (88.)*	0.15	0.0781	12.8	266.	57.	4.	-0.03*	0.06*
03 Oct 83	632	9.10	26. (20.)	0.21	0.1094	9.1	270.	38.	5.	0.02	0.01
	1432	7.45	21. (12.)	0.18	0.1094	9.1	276.	48.	5.	-0.01	0.05
	2232	10.29	19. (12.)	0.17	0.0781	12.8	265.	58.	5.	-0.01	0.04
04 Oct 83	632	8.38	12. (8.)	0.14	0.0781	12.8	269.	51.	4.	0.01	0.02
	1432	7.83	8. (6.)	0.11	0.0781	12.8	262.	41.	3.	-0.03	0.01
	2232	10.70	10. (9.)	0.13	0.0781	12.8	285.	56.	3.	0.00	-0.01
05 Oct 83	632	7.90	26. (15.)	0.20	0.0781	12.8	267.	51.	5.	0.01	-0.02
	1432	8.61	40. (30.)	0.25	0.1563	6.4	244.	35.	9.	-0.07	0.04
	2232	10.62	52. (38.)	0.29	0.2500	4.0	283.	45.	8.	0.00	0.01
06 Oct 83	632	7.27	16. (10.)	0.16	0.0781	12.8	264.	47.	6.	0.00	-0.01
	1432	9.25	10. (7.)	0.13	0.0781	12.8	259.	52.	4.	0.00	0.04
	2232	10.08	14. (10.)	0.15	0.0781	12.8	276.	52.	5.	-0.03	0.02
07 Oct 83	632	7.03	8. (5.)	0.11	0.0781	12.8	273.	45.	3.	0.00	-0.01
	1432	9.98	8. (7.)	0.11	0.0781	12.8	250.	45.	3.	-0.03	0.03
	2232	9.35	7. (364.)*	0.11	0.0781	12.8	256.	75.	2.	0.00*	0.09*
08 Oct 83	632	7.29	7. (3.)	0.11	0.0781	12.8	261.	51.	2.	0.00	0.02
	1432	10.47	19. (11.)	0.17	0.2500	4.0	267.	51.	5.	-0.01	0.01
	2232	8.63	8. (5.)	0.11	0.0938	10.7	252.	50.	2.	0.00	0.00
09 Oct 83	632	7.76	10. (4.)	0.13	0.0938	10.7	252.	52.	3.	-0.01	0.05
	1432	10.70	309. (441.)*	0.70	0.2031	4.9	227.	41.	88.	-0.01*	0.15*
	2232	8.08	105. (151.)*	0.41	0.1719	5.8	257.	39.	30.	0.01*	-0.01*
10 Oct 83	632	8.51	269. (176.)	0.66	0.1719	5.8	248.	35.	89.	-0.01	0.01
	1432	10.69	495. (318.)	0.89	0.1563	6.4	241.	37.	110.	-0.01	-0.01
	2232	7.80	132. (86.)	0.46	0.2500	4.0	245.	34.	21.	0.00	-0.04

TABLE VII-2-2 (Cont.)

WA CLIMATE SUMMARY - MA 26 AUGUST 1983 7 OCTOBER 1983 SEA DATA 635-12

DATE	TIME	$\bar{h}$ (m)	E_T(cm^2)	$H_{1/3}$(m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P(cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
11 Oct 83	632	9.19	95. (59.)	0.39	0.1563	6.4	255.	40.	15.	-0.02	0.03
	1432	10.28	265. (149.)	0.65	0.2500	4.0	271.	40.	85.	-0.01	-0.04
	2232	7.60	284. (166.)	0.67	0.2500	4.0	285.	39.	64.	-0.03	-0.05
12 Oct 83	632	9.51	164. (105.)*	0.51	0.2500	4.0	258.	38.	40.	-0.01	1.01*
	1432	9.64	110. (61.)	0.42	0.2500	4.0	256.	59.	17.	0.00	-0.03
	2232	7.72	299. (171.)	0.69	0.2031	4.9	293.	44.	88.	-0.03	0.03
13 Oct 83**	632	9.77	223. (80.)	0.60	0.2500	4.0	----	5.	30.	-0.01	0.06**
	1432	9.02	120. (66.)	0.44	0.1406	7.1	266.	51.	19.	-0.01	-0.01
	2232	8.07	71. (35.)	0.34	0.1094	9.1	278.	50.	18.	0.00	0.01
14 Oct 83	632	9.78	99. (43.)	0.40	0.0938	10.7	269.	53.	24.	0.01	0.04
	1432	8.49	55. (71.)	0.30	0.1250	8.0	276.	42.	17.	0.00	0.00
	2232	8.58	36. (58.)	0.24	0.1094	9.1	265.	49.	16.	-0.01	0.00
15 Oct 83	632	9.55	23. (69.)	0.19	0.1094	9.1	261.	58.	7.	-0.01	-0.01
	1432	8.16	14. (7.)	0.15	0.1094	9.1	269.	52.	5.	0.00	-0.01
	2232	9.12	64. (33.)	0.32	0.2188	4.6	212.	43.	11.	-0.01	0.01
16 Oct 83	632	9.37	56. (27.)	0.30	0.1875	5.3	232.	47.	16.	-0.01	-0.02
	** 1417	7.76	27. (8.)	0.21	0.0156	64.0	----	6.	10.	-0.15	0.07**
17 Oct 83	632	9.08	44. (14.)	0.27	0.2500	4.0	227.	54.	8.	-0.01	-0.02
	1432	8.11	17. (38.)	0.16	0.0938	10.7	267.	61.	4.	-0.01	0.01
	2232	9.89	23. (8.)	0.19	0.0938	10.7	260.	62.	11.	-0.01	0.02
18 Oct 83	632	8.58	19. (8.)	0.17	0.0938	10.7	272.	58.	5.	0.00	0.00
	1432	8.14	12. (5.)	0.14	0.0938	10.7	278.	57.	4.	-0.01	0.01
	2232	10.06	17. (7.)	0.17	0.0938	10.7	273.	57.	4.	0.00	0.00
19 Oct 83	632	8.37	66. (29.)	0.33	0.2500	4.0	220.	46.	23.	0.00	-0.01
	1432	8.52	49. (22.)	0.28	0.2500	4.0	238.	47.	9.	-0.02	0.01
	2232	10.24	46. (354.)*	0.27	0.2344	4.3	225.	51.	13.	-0.01*	3.06*
20 Oct 83	632	8.15	220. (95.)	0.59	0.1563	6.4	238.	49.	54.	0.01	-0.03
	1432	8.87	218. (99.)	0.59	0.1563	6.4	226.	48.	44.	-0.01	0.00
	2232	10.09	299. (131.)	0.69	0.1563	6.4	248.	47.	58.	0.00	-0.01

DATE	TIME	$\bar{h}$ (m)	E_T(cm^2)	$H_{1/3}$(m)	Peak F (sec^{-1})	Peak T (sec)	α_o	P(α_o)	E_P(cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)
21 Oct 83	632	7.87	235. (101.)	0.61	0.1719	5.8	263.	52.	66.	0.01	-0.04
	1432	9.33	566. (223.)	0.95	0.1406	7.1	256.	48.	167.	-0.04	-0.04
	2232	9.80	575. (242.)	0.96	0.1406	7.1	251.	50.	90.	0.00	-0.02
22 Oct 83	632	7.74	239. (92.)	0.62	0.1250	8.0	266.	53.	64.	-0.02	-0.04
	1432	9.61	227. (95.)	0.60	0.1094	9.1	265.	50.	37.	-0.01	0.01
	2232	9.42	340. (136.)	0.74	0.1250	8.0	273.	49.	69.	0.00	-0.03
23 Oct 83	632	7.61	224. (96.)	0.60	0.0938	10.7	277.	50.	70.	-0.01	-0.01
	1432	9.99	334. (134.)	0.73	0.0938	10.7	268.	51.	109.	-0.04	0.00
	2232	8.99	268. (104.)	0.65	0.0781	12.8	273.	50.	84.	-0.02	-0.02
24 Oct 83	632	7.72	270. (102.)	0.66	0.0781	12.8	274.	53.	100.	-0.02	0.02
	1432	10.52	1534. (533.)	1.57	0.1406	7.1	239.	54.	523.	0.01	-0.03
	2232	8.67	1704. (724.)	1.65	0.1250	8.0	255.	47.	370.	0.01	0.08
25 Oct 83	632	8.39	1212. (635.)	1.39	0.1094	9.1	260.	48.	279.	0.00	-0.06
	1432	10.75	2160. (872.)	1.86	0.1094	9.1	252.	49.	475.	0.00	-0.01
	2232	8.34	865. (359.)	1.18	0.1094	9.1	265.	50.	231.	0.00	-0.05
26 Oct 83	632	8.67	848. (380.)	1.16	0.0938	10.7	270.	47.	236.	-0.01	0.03
	1432	10.50	895. (400.)	1.20	0.0781	12.8	277.	49.	308.	0.00	-0.01
	2232	7.62	187. (70.)	0.55	0.0781	12.8	267.	53.	60.	0.00	-0.01
27 Oct 83	632	8.99	96. (30.)	0.39	0.0781	12.8	262.	57.	39.	-0.01	0.02
MEAN		8.92	120. (74.)							-0.01	0.01
S.D.		1.00	277. (131.)							0.02	0.04

To summarize the second measurement period, wave energy was low, except for one storm event on 24-25 October 1983. Observations of large amounts of suspended material in the water column two days later on 27 October indicate that significant sand transport occurs in this area during storm conditions. However, sand cover in the vicinity of the tripod did not appear to have changed, and small scale sand ripples ($<$15 cm) were still observed. In comparison with wave data from the first measurement interval, the second set of data shows higher energy overall, with one major storm event, and several more minor events. The largest waves uniformly approach from the east-northeast, with a minor higher-frequency mode from the southeast.

The third deployment, 10 November to 14 December, was cut short when divers discovered that the EMCM attachment hardware had failed, allowing the EMCM to rotate around the tripod axis approximately 30° in the horizontal to either side of its original location. When the hardware failed is not known, but inconsistent directional estimates present for most of the period indicate failure occurred following the first storm on 10-11 November 1983.

An attempt to reconstruct directional information was made by analyzing and comparing wind velocity, wave periods, and wave directions for similar events during the first and second deployments and applying these results to similar events during the third deployment. Corrected wave directional estimates derived from this method are included in Table VII-2-3, and are marked accordingly.

This correction was obtained by correlating the mean directional estimates for waves with periods of 9.1 seconds, 10.6 seconds and 12.8 seconds in the previous data sets with hourly wind velocity data gathered at the Otis Air National Guard weather station, Otis AFB, Cape Cod, MA. Mean directional estimates for waves of these periods were 260° TN for 9.1 second waves (direction of propagation) with standard deviations of 35°, 31°, and 38°, respectively. The wind data for these waves correlated as well, giving a general wind pattern coming out of the E/NE. Subsequently, directional estimates for waves of the same periods and/or with similar wind conditions were examined in this third deployment, and it was possible in some cases that a correction within the standard deviation of 38° could be made to bring the mean directions to approximately 260-265° TN. No attempt was made to correct mean flow directions.

Over the 35 day deployment, wave energy averaged 120 cm^2 in variance, while the mean significant wave height was 0.47 m. The mean peak wave period was just over 8.5 seconds. This data set is the most energetic to date with three major events and two or three minor ones recorded. The three major events occurred on 10-11 November, 15-16 November, and 4-5 December; the latter two producing peak significant wave heights exceeding 2.0 m and peak total variances exceeding 2500 cm^2 for

TABLE VII-2-3

Analysis of the 63 day wave/tide record, measured at Green Harbor, Massachusetts with a Sea Data 635-12 Values are recorded at 8 hour intervals for the following parameters:

$\bar{h}$	= mean water depth (m)
$E_T(\langle\eta^2\rangle)$	= total energy varience in wave (cm^2) This parameter is proportional to the amount of energy in the wave. Comparison values calculated from pressure and velocity are presented. Velocity calculated values are in parentheses.
$H_{1/3}$	= significant wave height (m) This parameter is derived directly from E_T. Where: $H_{1/3} = 4\sqrt{\langle\eta^2\rangle}$
Peak F	= peak wave frequency (sec^{-1})
Peak T	= peak wave period = $\frac{1}{\text{peak wave frequency}}$
α_o	= direction of wave propagation, measured in degrees clockwise from true north
$P(\alpha_o)$	= angular spread of direction of propagation of the wave field
E_p	= energy in peak frequency variance (cm^2)
$\bar{U},\bar{V}$	= components of current velocity (m/sec); U is positive to the north, V is positive to the east
W_S	= wind speed in knots "( )" indicates max gusts
W_D	= direction from which the wind is originating in degrees ("E"indicates estimated)
S.D.	= standard deviation of indicated quantity

* Indicates corrected directional estimate. Non * values are uncorrected directional estimates, and are not reliable due to probe rotation

** Initial probe rotation occurred prior to this run.

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	W_s	W_D
10 NOV 83 -	1546	10.15	64. (65.)	0.32	0.2344	4.3	45.	30.	15.	0.01	-0.02	05	140
10 NOV 83 -	2346	8.49	1435.(1565.)	1.52	0.1563	6.4	332.*	26.	417.	0.04	0.14	17	150
11 NOV 83 -	746	8.58	475. (521.)	0.87	0.1094	9.1	266.*	23.	156.	0.02	-0.09	10	200
11 NOV 83 -	1546	10.15	548. (502.)	0.94	0.1094	9.1	4.**	33.	142.	0.02	0.02	11	170
11 NOV 83 -	2346	7.91	164. (177.)	0.51	0.1250	8.0	282.	25.	61.	-0.01	-0.04	15	240
12 NOV 83 -	746	8.85	93. (94.)	0.39	0.1094	9.1	74.	24.	34.	-0.01	-0.06	14	260
12 NOV 83 -	1546	9.64	38. (48.)	0.25	0.0938	10.7	352.	34.	13.	-0.04	0.01	16	310
12 NOV 83 -	2346	7.75	37. (42.)	0.24	0.1094	9.1	3.	27.	7.	-0.04	-0.03	12	320
13 NOV 83 -	746	9.28	38. (47.)	0.25	0.1719	5.8	39.	27.	4.	-0.03	-0.06	13	320
13 NOV 83 -	1546	9.35	116. (115.)	0.43	0.1875	5.3	51.	20.	27.	0.01	0.05	08	030
13 NOV 83 -	2346	8.01	38. (42.)	0.25	0.2031	4.9	43.	32.	7.	-0.01	-0.04	00	000
14 NOV 83 -	746	9.79	208. (215.)	0.58	0.2500	4.0	360.	29.	55.	0.00	-0.04	08	080
14 NOV 83 -	1546	9.06	235. (249.)	0.61	0.2031	4.9	35.	22.	41.	-0.02	0.05	17	060
14 NOV 83 -	2346	8.25	188. (199.)	0.55	0.1719	5.8	37.	23.	45.	-0.01	-0.03	12	070
15 NOV 83 -	746	10.09	151. (154.)	0.49	0.2344	4.3	54.	29.	28.	-0.01	0.01	10	090
15 NOV 83 -	1546	8.63	129. (136.)	0.45	0.1563	6.4	311.	20.	18.	-0.01	0.04	08	080
15 NOV 83 -	2346	8.58	617. (613.)	0.99	0.2188	4.6	300.*	22.	151.	0.07	-0.06	17	120
16 NOV 83 -	746	10.20	2534.(2503.)	2.01	0.1563	6.4	290.*	23.	509.	0.08	-0.13	20(28)	150
16 NOV 83 -	1546	8.18	844. (849.)	1.16	0.1094	9.1	243.*	21.	342.	0.00	-0.03	14(20)	220
16 NOV 83 -	2346	8.93	373. (386.)	0.77	0.0938	10.7	301.*	26.	130.	0.00	-0.07	08	240
17 NOV 83 -	746	10.01	277. (297.)	0.67	0.0938	10.7	281.*	29.	85.	-0.01	0.01	08	250
17 NOV 83 -	1546	7.66	135. (146.)	0.46	0.1094	9.1	260.*	27.	51.	-0.02	-0.02	10	270
17 NOV 83 -	2346	9.18	79. (85.)	0.36	0.0938	10.7	49.	22.	34.	-0.02	-0.04	22(30)	280
18 NOV 83 -	746	9.77	54. (58.)	0.30	0.0938	10.7	5.	29.	20.	0.00	-0.01	14(20)	300
18 NOV 83 -	1546	7.45	44. (47.)	0.26	0.0781	12.8	343.	30.	16.	-0.02	0.00	08	290
18 NOV 83 -	2346	9.45	28. (25.)	0.21	0.0938	10.7	9.	30.	12.	0.01	-0.07	10	300
19 NOV 83 -	746	9.45	15. (18.)	0.15	0.0938	10.7	307.	33.	4.	-0.02	0.02	04	300
19 NOV 83 -	1546	7.42	12. (13.)	0.14	0.0781	12.8	330.	35.	3.	0.00	-0.04	00	000
19 NOV 83 -	2346	9.92	15. (17.)	0.16	0.0781	12.8	267.	49.	6.	-0.01	-0.03	00	000

TABLE VII-2-3 (Cont.)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 10 NOV - 14 DEC 1983

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)		$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{\bar{U}}$ (m/sec)	$\bar{\bar{V}}$ (m/sec)	W_s	W_D
20 NOV 83 -	746	9.26	11.	(14.)	0.13	0.0781	12.8	324.	30.	4.	-0.03	0.03	00	000
20 NOV 83 -	1546	7.67	15.	(18.)	0.16	0.0781	12.8	26.	27.	6.	0.03	-0.06	08	170 E
20 NOV 83 -	2346	10.24	106.	(116.)	0.41	0.2500	4.0	172.	28.	46.	-0.01	-0.08	10	160 E
21 NOV 83 -	746	8.82	127.	(137.)	0.45	0.2188	4.6	187.	27.	31.	0.00	-0.01	06	150 E
21 NOV 83 -	1546	8.09	34.	(32.)	0.23	0.1250	8.0	286.	23.	8.	0.00	-0.09	12	290
21 NOV 83 -	2346	10.15	57.	(59.)	0.30	0.1406	7.1	61.	26.	12.	-0.03	-0.02	13	250
22 NOV 83 -	746	8.27	28.	(30.)	0.21	0.1406	7.1	24.	24.	7.	-0.02	0.02	12	260
22 NOV 83 -	1546	8.61	26.	(26.)	0.20	0.1094	9.1	6.	26.	7.	0.02	-0.08	13	310
22 NOV 83 -	2346	10.17	24.	(31.)	0.20	0.1406	7.1	40.	36.	5.	-0.04	0.04	00	000
23 NOV 83 -	746	7.96	64.	(70.)	0.32	0.2031	4.9	26.	26.	12.	-0.03	0.01	07	320
23 NOV 83 -	1546	9.27	132.	(143.)	0.46	0.1719	5.8	24.	28.	26.	-0.01	-0.08	08	040
23 NOV 83 -	2346	9.79	75.	(78.)	0.35	0.2344	4.3	37.	41.	10.	-0.03	0.07	00	000
24 NOV 83 -	746	7.76	83.	(90.)	0.36	0.1250	8.0	331.	24.	27.	0.00	-0.02	08	170
24 NOV 83 -	1546	9.92	184.	(184.)	0.54	0.2500	4.0	154.	23.	60.	0.03	-0.12	12	170
24 NOV 83 -	2346	9.10	80.	(88.)	0.36	0.2500	4.0	113.	29.	16.	-0.02	-0.02	18	210
25 NOV 83 -	746	7.75	143.	(131.)	0.48	0.2500	4.0	121.	31.	36.	0.02	-0.15	12	170
25 NOV 83 -	1546	10.30	74.	(83.)	0.34	0.2188	4.6	6.	30.	12.	-0.04	-0.06	26(40)	280
25 NOV 83 -	2346	7.86	42.	(48.)	0.26	0.0938	10.7	331.	31.	10.	-0.02	-0.02	18(28)	270
26 NOV 83 -	746	7.87	16.	(18.)	0.16	0.0781	12.8	305.	33.	5.	0.00	-0.06	18	260
26 NOV 83 -	1546	9.99	16.	(22.)	0.16	0.0781	12.8	341.	52.	6.	-0.03	-0.03	17(24)	270
26 NOV 83 -	2346	7.67	8.	(9.)	0.12	0.0781	12.8	340.	36.	3.	0.00	0.00	10	280
27 NOV 83 -	746	8.52	9.	(10.)	0.12	0.0781	12.8	38.	35.	2.	0.01	-0.07	10	290
27 NOV 83 -	1546	10.04	11.	(13.)	0.13	0.2344	4.3	28.	47.	3.	-0.03	0.00	08	300
27 NOV 83 -	2346	7.69	17.	(19.)	0.17	0.2188	4.6	25.	27.	3.	-0.03	0.01	06	320

TABLE VII-2-3 (Cont.)

WAVE CLIMATE - GREEN HARBOR, MASSA ETTS - SEA DATA 635-12 10 NOV - 14 C 1983 e 3 of 4

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	W_s	W_D
28 NOV 83 -	746	9.53	84. (83.)	0.37	0.2344	4.3	32.	31.	18.	0.02	-0.01	00	000
28 NOV 83 -	1546	9.83	89. (85.)	0.38	0.1875	5.3	44.	27.	18.	0.03	0.02	04	110
28 NOV 83 -	2346	7.52	269. (239.)	0.66	0.2344	4.3	285.*	33.	83.	0.04	-0.06	10(20)	150
29 NOV 83 -	746	10.16	403. (351.)	0.80	0.2188	4.6	285.*	35.	101.	0.05	-0.10	05	160
29 NOV 83 -	1546	8.93	121. (128.)	0.44	0.1250	8.0	308.	20.	37.	-0.04	0.00	10	270
29 NOV 83 -	2346	7.67	54. (51.)	0.29	0.1250	8.0	344.	21.	18.	0.00	-0.05	10	270
30 NOV 83 -	746	10.25	24. (25.)	0.20	0.1094	9.1	325.	36.	5.	-0.02	-0.04	08	250
30 NOV 83 -	1546	7.88	11. (12.)	0.13	0.1094	9.1	299.	23.	3.	-0.02	0.00	16	240
30 NOV 83 -	2346	8.31	9. (9.)	0.12	0.0938	10.7	29.	32.	2.	0.01	-0.06	12	280
1 DEC 83 -	746	10.38	7. (8.)	0.10	0.0781	12.8	1.	48.	1.	0.00	-0.02	12	280
1 DEC 83 -	1546	7.53	5. (6.)	0.09	0.1094	9.1	290.	32.	1.	-0.04	0.01	06	320
1 DEC 83 -	2346	9.09	6. (7.)	0.10	0.0625	16.0	355.	42.	1.	0.01	-0.05	04	280
2 DEC 83 -	746	10.30	8. (8.)	0.11	0.0625	16.0	351.	58.	1.	-0.01	0.06	06	290
2 DEC 83 -	1546	7.16	6. (5.)	0.09	0.0781	12.8	2.	35.	2.	-0.01	-0.01	10	270
2 DEC 83 -	2346	9.59	5. (6.)	0.09	0.0781	12.8	339.	55.	3.	-0.01	-0.02	06	260
3 DEC 83 -	746	9.62	4. (4.)	0.08	0.0781	12.8	5.	54.	2.	0.00	0.00	09	280
3 DEC 83 -	1546	7.19	9. (9.)	0.12	0.0781	12.8	346.	37.	1.	-0.02	-0.03	02	360
3 DEC 83 -	2346	10.10	36. (34.)	0.24	0.2344	4.3	19.	27.	10.	0.00	-0.03	00	000
4 DEC 83 -	746	9.22	138. (127.)	0.47	0.2500	4.0	260.*	41.	43.	-0.02	0.07	08	090
4 DEC 83 -	1546	7.86	1191. (781.)	1.38	0.1875	5.3	265.*	38.	267.	0.04	-0.03	20(27)	090 E
4 DEC 83 -	2346	10.53	2640.(2098.)	2.06	0.1094	9.1	267.*	33.	456.	0.00	0.06	18(26)	040 E
5 DEC 83 -	746	8.83	1765.(1460.)	1.68	0.0938	10.7	258.*	25.	692.	0.00	0.05	12	040
5 DEC 83 -	1546	8.26	1975.(1527.)	1.78	0.0938	10.7	259.*	31.	706.	-0.02	-0.02	10	340
5 DEC 83 -	2346	10.31	894. (707.)	1.20	0.0938	10.7	276.*	31.	325.	0.01	-0.01	06	310
6 DEC 83 -	746	8.22	393. (313.)	0.79	0.0938	10.7	279.*	26.	100.	0.01	0.03	00	000
6 DEC 803 -	1546	8.76	483. (323.)	0.88	0.2500	4.0	269.*	46.	105.	-0.01	-0.14	10	140 E
6 DEC 83 -	2346	9.93	775. (569.)	1.11	0.1719	5.8	268.*	34.	125.	-0.04	-0.10	16(24)	210 E

TABLE VII-2-3 (Cont.)

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)		$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	W_s	W_D
7 DEC 83 -	746	7.54	64.	(58.)	0.32	0.1094	9.1	275.*	29.	22.	-0.04	-0.03	36(46)	250
7 DEC 83 -	1546	8.89	17.	(17.)	0.16	0.0781	12.8	267.*	36.	5.	-0.04	-0.05	26(40)	260
7 DEC 83 -	2346	9.00	259.	(18.)	0.18	0.0781	12.8	259.*	41.	6.	-0.04	0.00	22(32)	270
8 DEC 83 -	746	7.51	11.	(10.)	0.13	0.0781	12.8	272.*	29.	4.	-0.01	-0.02	12(20)	280
8 DEC 83 -	1546	9.47	12.	(12.)	0.14	0.0781	12.8	247.*	41.	5.	0.00	-0.08	14	290
8 DEC 83 -	2346	8.72	10.	(11.)	0.13	0.0938	10.7	271.*	34.	3.	0.01	0.03	00	000
9 DEC 83 -	746	7.79	7.	(8.)	0.11	0.0938	10.7	259.*	28.	2.	-0.03	-0.04	00	000
9 DEC 83 -	1546	9.97	7.	(8.)	0.10	0.0781	12.8	235.*	48.	2.	-0.01	-0.02	06	240
9 DEC 83 -	2346	8.60	7.	(6.)	0.10	0.0781	12.8	269.*	41.	2.	-0.01	-0.01	00	000
10 DEC 83 -	746	8.12	8.	(8.)	0.11	0.0781	12.8	264.*	32.	2.	0.00	-0.04	04	240
10 DEC 83 -	1546	10.02	12.	(13.)	0.14	0.0938	10.7	249.*	51.	3.	-0.03	-0.04	07	240
10 DEC 83 -	2346	8.24	11.	(9.)	0.13	0.0938	10.7	263.*	30.	5.	-0.01	0.01	00	000
11 DEC 83 -	746	8.69	419.	(368.)	0.82	0.1406	7.1	254.*	26.	98.	0.03	0.04	10	040
11 DEC 83 -	1546	10.03	345.	(329.)	0.74	0.1563	6.4	250.*	22.	82.	0.01	0.02	10	070
11 DEC 83 -	2346	8.00	154.	(134.)	0.50	0.1719	5.8	257.*	26.	23.	0.02	0.03	09	090
12 DEC 83 -	746	9.19	724.	(467.)	1.08	0.2188	4.6	280.*	47.	211.	0.01	-0.03	12	130 E
12 DEC 83 -	1546	9.88	777.	(519.)	1.11	0.2031	4.9	247.*	38.	143.	0.01	-0.06	19	120 E
12 DEC 83 -	2346	7.98	585.	(392.)	0.97	0.1094	9.1	278.*	33.	166.	0.00	-0.06	14(20)	150 E
13 DEC 83 -	746	9.38	501.	(352.)	0.90	0.1094	9.1	274.*	33.	155.	-0.03	-0.08	10	140 E
13 DEC 83 -	1546	9.23	201.	(173.)	0.57	0.1250	8.0	32.	24.	46.	0.00	0.01	14	120 E
13 DEC 83 -	2346	7.92	126.	(104.)	0.45	0.1250	8.0	35.	34.	24.	0.00	0.00	10	140 E
14 DEC 83 -	746	9.78	293.	(234.)	0.68	0.0938	10.7	34.	32.	90.	-0.01	-0.01	10	190

* - Corrected Directional Estimate

		$\bar{h}$	E_T		$H_{1/3}$	Peak T
MEAN		8.92	258.	225.	0.47	8.64
S.D.		0.95	484.	419.	0.43	3.29

the first time since the measurement period began in June. Average wave energy was high, dominated by three major storm events. Directional estimates are unreliable due to movement of the EMCM although an attempt was made to recover this information as described above.

Following the mounting hardware failure in December 1983, the EMCM probe failed when exposed to cold ($2^{o}C$) water. Since the failure was intermittent, isolation of the problem took considerable effort on the part of WHOI, Sea Data, and Marsh-McBirney. Subsequently, the probe has been replaced, althought the wave gauge was not re-deployed until 23 February 1984 due to funding limitations.

Over the 100 day measurement period 23 February to 1 June 1984, the mean significant wave height was 0.59 m. The mean peak wave period was just over 9.2 seconds (Table VII-2-4). Variances as calculated from pressure agree well with those calculated from velocity except during the high energy events. This is attributed to EMCM undersensitivity at high wave velocities. Wave propagation was toward the west (269^{o}TN) consistent with previous data sets. Mean current flow for the period was toward the northwest (340^{o}TN). This is not consistent with the first two measurement intervals and the discrepancy will be discussed in the final report.

The direction data for the third data set was unreliable due to movement of the EMCM as discussed previously. The mounting hardware appeared unreliable even after repairs and consequently a new mounting device was installed on March 7, 1984. This was accomplished with no loss of data and accounts for the change in the height of the current meter as noted in Table VII-1-4.

This data set is the most energetic to date, with seven major events and other more minor ones recorded. The seven major events occurred on 28-29 February, 9-10 March, 13-15 March, 18-20 March, 29-31 March, 5 April, and 8-12 April. These events produced significant wave heights exceeding 1.0 m and peak total variances exceeding 1000 cm^2, with the storm on 29-31 March producing significant wave heights exceeding 3.0 m and peak total variance exceeding 6900 cm^2 for the first time since the measurement period began in June 1983.

In conclusion, average wave energy was high, dominated by seven major storm events. The largest waves uniformly approach from the east-northeast. The mean current flow is toward the northwest which is inconsistent with the first two data sets.

Table VII-2-4

Analysis of the 100 day wave/tide record, measured at Green Harbor, Massachusetts with a Sea Data 635-12. Values are recorded at 8 hour intervals for the following parameters:

$\bar{h}$	= mean water depth (m)
E_T ($\langle\eta^2\rangle$)	= total energy variance in wave (cm^2) This parameter is proportional to the amount of energy in the wave. Comparison values calculated from pressure and velocity are presented. Velocity calculated values are in parentheses.
$H_{1/3}$	= significant wave height (m) This parameter is derived directly from E_T Where: $H_{1/3} = 4 \;\; \langle\eta^2\rangle$
Peak F	= peak wave frequency (sec^{-1})
Peak T	= peak wave period = $\dfrac{1}{\text{peak wave frequency}}$
α_o	= direction of peak wave propagation, measured in degrees clockwise from true north
$P(\alpha_o)$	= angular spread of direction of propagation of the peak wave
E_P	= energy variance in peak frequency (cm^2)
$\bar{U}$, $\bar{V}$	= components of current velocity (m/sec); relative to probe orientation.
C_s	= current speed (m/sec) as calculated from $\bar{U}$, $\bar{V}$
C_D	= direction toward which the current is flowing in degrees T.N. as calculated from $\bar{U}$, $\bar{V}$
S.D.	= standard deviation of indicated quantity

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	
23 FEB 84 -	1655	9.95	4.(6.)	0.08	0.0781	12.8	277.	53.	2.	0.00	-0.02	0.02	114.
24 FEB 84 -	55	8.20	5.(6.)	0.09	0.0938	10.7	273.	32.	1.	0.05	0.03	0.06	227.
24 FEB 84 -	855	8.79	250.(267.)	0.63	0.1563	6.4	278.	26.	42.	0.07	0.02	0.07	211.
24 FEB 84 -	1655	9.75	597.(521.)	0.98	0.1406	7.1	263.	27.	182.	0.00	0.07	0.07	286.
25 FEB 84 -	55	7.77	369.(346.)	0.77	0.1406	7.1	267.	23.	69.	0.08	0.04	0.09	223.
25 FEB 84 -	855	9.28	209.(196.)	0.58	0.1250	8.0	258.	25.	39.	0.00	-0.01	0.01	101.
25 FEB 84 -	1655	9.04	106.(105.)	0.41	0.0938	10.7	276.	33.	21.	0.07	0.02	0.07	216.
26 FEB 84 -	55	7.74	36.(35.)	0.24	0.0938	10.7	277.	29.	8.	0.01	0.04	0.04	272.
26 FEB 84 -	855	9.79	45.(50.)	0.27	0.2344	4.3	222.	32.	7.	-0.05	0.05	0.07	333.
26 FEB 84 -	1655	8.36	80.(75.)	0.36	0.1563	6.4	246.	23.	20.	-0.01	0.07	0.07	301.
27 FEB 84 -	55	7.97	24.(24.)	0.19	0.1563	6.4	254.	28.	4.	-0.01	0.01	0.01	315.
27 FEB 84 -	855	10.13	36.(39.)	0.24	0.1875	5.3	232.	36.	7.	-0.01	-0.01	0.01	72.
27 FEB 84 -	1655	8.04	9.(10.)	0.12	0.0938	10.7	285.	22.	2.	0.02	0.02	0.03	235.
28 FEB 84 -	55	8.45	6.(7.)	0.10	0.0938	10.7	283.	30.	1.	-0.04	0.01	0.05	2.
28 FEB 84 -	855	10.30	707.(690.)	1.06	0.2031	4.9	273.	30.	151.	0.07	0.02	0.08	210.
28 FEB 84 -	1655	7.96	2220.(981.)	1.88	0.1563	6.4	299.	26.	421.	0.08	-0.04	0.08	173.
29 FEB 84 -	55	9.07	1703.(490.)	1.65	0.0938	10.7	280.	26.	692.	0.01	-0.01	0.01	144.
29 FEB 84 -	855	9.90	743.(656.)	1.09	0.0938	10.7	269.	37.	301.	0.01	0.04	0.04	272.
29 FEB 84 -	1655	7.37	253.(232.)	0.64	0.0938	10.7	284.	31.	101.	0.03	0.02	0.03	225.
1 MAR 84 -	55	9.16	80.(82.)	0.36	0.0938	10.7	280.	28.	39.	0.02	0.02	0.03	250.
1 MAR 84 -	855	9.50	43.(45.)	0.26	0.0938	10.7	274.	28.	11.	0.06	0.02	0.06	215.
1 MAR 84 -	1655	7.32	18.(19.)	0.17	0.0938	10.7	285.	32.	5.	0.02	0.04	0.04	263.
2 MAR 84 -	55	9.45	14.(13.)	0.15	0.0781	12.8	264.	36.	4.	0.00	0.01	0.01	265.
2 MAR 84 -	855	9.09	10.(13.)	0.12	0.0781	12.8	284.	37.	3.	0.06	0.07	0.09	250.
2 MAR 84 -	1655	7.38	6.(7.)	0.10	0.0781	12.8	293.	31.	2.	0.00	0.05	0.05	291.
3 MAR 84 -	55	9.70	8.(8.)	0.11	0.0938	10.7	271.	38.	2.	0.01	0.00	0.01	187.
3 MAR 84 -	855	8.84	7.(11.)	0.11	0.0781	12.8	284.	43.	3.	0.05	0.08	0.09	258.
3 MAR 84 -	1655	7.70	14.(12.)	0.15	0.0781	12.8	270.	36.	5.	-0.03	0.03	0.05	336.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_*	
4 MAR 84 -	55	10.00	17.(17.)	0.16	0.0781	12.8	261.	51.	6.	-0.01	0.03	0.03	317.
4 MAR 84 -	855	8.48	52.(56.)	0.29	0.2031	4.9	238.	27.	8.	0.04	0.05	0.07	248.
4 MAR 84 -	1655	8.02	44.(40.)	0.26	0.0781	12.8	280.	28.	20.	0.00	0.00	0.00	319.
5 MAR 84 -	55	10.17	51.(42.)	0.29	0.0781	12.8	287.	57.	19.	0.01	0.00	0.01	200.
5 MAR 84 -	855	8.11	63.(69.)	0.32	0.0781	12.8	287.	23.	36.	0.05	0.04	0.06	233.
5 MAR 84 -	1655	8.41	138.(126.)	0.47	0.2500	4.0	304.	28.	39.	-0.05	0.01	0.05	2.
6 MAR 84 -	55	10.09	126.(126.)	0.45	0.2188	4.6	302.	31.	32.	0.01	0.04	0.04	271.
6 MAR 84 -	855	7.75	81.(81.)	0.36	0.0781	12.8	288.	21.	20.	0.06	0.03	0.07	226.
6 MAR 84 -	1655	8.78	113.(95.)	0.43	0.0781	12.8	278.	22.	51.	-0.01	0.04	0.04	309.
7 MAR 84 -	55	9.88	82.(86.)	0.36	0.0781	12.8	259.	30.	32.	0.03	0.00	0.03	204.
7 MAR 84 -	855	7.54	81.(81.)	0.36	0.0938	10.7	288.	31.	25.	0.08	0.04	0.09	227.
7 MAR 84 -	1655	9.15	45.(45.)	0.27	0.0781	12.8	253.	34.	15.	0.05	0.09	0.11	359.
8 MAR 84 -	55	9.54	54.(56.)	0.29	0.0781	12.8	272.	34.	16.	0.03	0.04	0.05	346.
8 MAR 84 -	855	7.48	42.(43.)	0.26	0.0781	12.8	266.	23.	12.	0.08	0.01	0.08	300.
8 MAR 84 -	1655	9.42	37.(45.)	0.24	0.0781	12.8	269.	22.	5.	0.06	0.06	0.08	342.
9 MAR 84 -	55	9.30	26.(26.)	0.21	0.0938	10.7	273.	36.	4.	0.04	0.00	0.04	290.
9 MAR 84 -	855	7.96	746.(705.)	1.09	0.1563	6.4	254.	24.	221.	0.05	-0.14	0.15	225.
9 MAR 84 -	1655	9.82	2716.(2469.)	2.08	0.1094	9.1	259.	32.	597.	0.02	-0.05	0.06	231.
10 MAR 84 -	55	9.14	1505.(1435.)	1.55	0.0938	10.7	269.	21.	481.	0.03	-0.05	0.06	242.
10 MAR 84 -	855	8.17	1143.(1062.)	1.35	0.0938	10.7	267.	28.	368.	0.08	0.03	0.09	314.
10 MAR 84 -	1655	9.72	806.(753.)	1.14	0.0938	10.7	266.	26.	280.	0.07	0.02	0.07	309.
11 MAR 84 -	55	8.41	477.(469.)	0.87	0.0938	10.7	275.	24.	193.	0.05	-0.03	0.05	266.
11 MAR 84 -	855	8.47	162.(136.)	0.51	0.0781	12.8	267.	27.	63.	0.04	0.13	0.14	8.
11 MAR 84 -	1655	9.48	31.(37.)	0.22	0.0781	12.8	257.	38.	8.	0.08	0.05	0.09	330.
12 MAR 84 -	55	7.79	9.(12.)	0.12	0.0938	10.7	277.	36.	2.	0.10	0.02	0.10	305.
12 MAR 84 -	855	9.21	8.(14.)	0.11	0.2500	4.0	211.	43.	2.	0.07	0.07	0.10	339.
12 MAR 84 -	1655	9.09	11.(15.)	0.13	0.0781	12.8	267.	33.	2.	0.08	-0.01	0.08	285.
13 MAR 84 -	55	7.72	12.(14.)	0.14	0.0938	10.7	276.	28.	2.	0.04	0.00	0.04	295.
13 MAR 84 -	855	9.84	20.(26.)	0.18	0.2500	4.0	222.	39.	4.	0.04	0.05	0.06	350.
13 MAR 84 -	1655	8.74	847.(864.)	1.16	0.2031	4.9	278.	26.	260.	0.02	0.01	0.02	319.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - [illegible] JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	[illegible]
14 MAR 84 -	55	7.99	1096.(1108.)	1.32	0.1094	9.1	284.	20.	350.	0.00	0.10	0.10	25.
14 MAR 84 -	855	10.53	2250.(2156.)	1.90	0.0938	10.7	260.	27.	764.	0.04	0.12	0.13	9.
14 MAR 84 -	1655	8.26	917.(928.)	1.21	0.1094	9.1	282.	29.	238.	-0.01	-0.01	0.01	172.
15 MAR 84 -	55	8.25	717.(682.)	1.07	0.0938	10.7	282.	24.	190.	0.08	0.06	0.10	333.
15 MAR 84 -	855	10.62	1242.(1112.)	1.41	0.1250	8.0	252.	27.	233.	0.03	0.06	0.06	2.
15 MAR 84 -	1655	7.51	549.(534.)	0.94	0.0781	12.8	270.	23.	121.	0.03	-0.05	0.06	237.
16 MAR 84 -	55	8.90	552.(508.)	0.94	0.0781	12.8	271.	28.	168.	0.06	0.11	0.12	356.
16 MAR 84 -	855	10.38	670.(568.)	1.04	0.0781	12.8	277.	41.	123.	0.03	0.00	0.03	291.
16 MAR 84 -	1655	6.92	303.(295.)	0.70	0.0938	10.7	281.	22.	89.	0.04	-0.02	0.05	267.
17 MAR 84 -	55	9.65	461.(427.)	0.86	0.0938	10.7	265.	30.	150.	0.06	0.12	0.13	356.
17 MAR 84 -	855	9.81	595.(515.)	0.98	0.0938	10.7	271.	28.	154.	0.06	0.06	0.08	338.
17 MAR 84 -	1655	6.92	679.(670.)	1.04	0.1406	7.1	262.	32.	139.	0.03	-0.08	0.08	228.
18 MAR 84 -	55	10.47	3198.(2928.)	2.26	0.1094	9.1	249.	20.	961.	0.02	0.00	0.02	295.
18 MAR 84 -	855	9.12	2341.(2103.)	1.94	0.1094	9.1	256.	26.	737.	0.03	-0.07	0.08	226.
18 MAR 84 -	1655	7.53	1559.(1452.)	1.58	0.0938	10.7	274.	26.	479.	0.03	-0.06	0.07	230.
19 MAR 84 -	55	10.92	2978.(2766.)	2.18	0.0938	10.7	250.	25.	647.	0.02	-0.02	0.03	260.
19 MAR 84 -	855	8.27	1592.(1531.)	1.60	0.0938	10.7	263.	32.	401.	0.05	-0.05	0.07	252.
19 MAR 84 -	1655	8.21	1487.(1366.)	1.54	0.0938	10.7	266.	41.	381.	0.04	0.01	0.04	314.
20 MAR 84 -	55	10.96	4105.(3931.)	2.56	0.0938	10.7	260.	26.	902.	0.07	-0.01	0.07	290.
20 MAR 84 -	855	7.61	1358.(1292.)	1.47	0.1094	9.1	267.	24.	356.	0.02	-0.07	0.07	218.
20 MAR 84 -	1655	8.95	778.(770.)	1.12	0.0938	10.7	276.	29.	236.	0.05	0.06	0.08	345.
21 MAR 84 -	55	10.53	865.(838.)	1.18	0.1094	9.1	260.	31.	155.	0.08	0.06	0.09	331.
21 MAR 84 -	855	7.13	607.(601.)	0.99	0.0938	10.7	280.	18.	158.	0.06	-0.03	0.07	272.
21 MAR 84 -	1655	9.40	431.(398.)	0.83	0.0938	10.7	261.	25.	167.	0.07	0.07	0.10	341.
22 MAR 84 -	55	9.82	710.(703.)	1.07	0.0938	10.7	259.	30.	114.	0.09	0.03	0.10	313.
22 MAR 84 -	855	7.08	224.(225.)	0.60	0.1094	9.1	283.	28.	61.	0.05	0.04	0.07	333.
22 MAR 84 -	1655	9.74	156.(133.)	0.50	0.0938	10.7	276.	37.	53.	0.06	0.17	0.18	5.
23 MAR 84 -	55	9.05	169.(166.)	0.52	0.1094	9.1	271.	30.	59.	0.05	0.01	0.05	306.
23 MAR 84 -	855	7.54	59.(59.)	0.31	0.1094	9.1	277.	28.	19.	0.04	0.09	0.10	1.
23 MAR 84 -	1655	9.84	65.(60.)	0.32	0.0938	10.7	274.	46.	18.	0.09	0.06	0.11	329.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - [illegible] JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	[illegible]
24 MAR 84 -	55	8.40	25.(30.)	0.20	0.0938	10.7	276.	25.	9.	0.10	0.01	0.10	304.
24 MAR 84 -	855	8.25	18.(21.)	0.17	0.0781	12.8	271.	23.	5.	0.06	0.07	0.09	347.
24 MAR 84 -	1655	9.62	19.(20.)	0.17	0.0938	10.7	273.	40.	6.	0.02	0.07	0.08	13.
25 MAR 84 -	55	8.04	12.(13.)	0.14	0.0781	12.8	275.	36.	3.	0.05	-0.02	0.06	274.
25 MAR 84 -	855	8.96	9.(10.)	0.12	0.0938	10.7	284.	35.	3.	0.01	0.06	0.06	13.
25 MAR 84 -	1655	9.21	11.(13.)	0.13	0.2344	4.3	235.	31.	2.	0.03	0.00	0.03	298.
26 MAR 84 -	55	7.80	7.(10.)	0.11	0.0781	12.8	269.	33.	2.	0.06	0.07	0.09	343.
26 MAR 84 -	855	9.52	179.(170.)	0.54	0.1875	5.3	243.	26.	45.	0.04	0.02	0.04	319.
26 MAR 84 -	1655	8.78	53.(57.)	0.29	0.2188	4.6	233.	28.	22.	0.05	-0.02	0.05	270.
27 MAR 84 -	55	8.01	11.(15.)	0.13	0.2500	4.0	234.	35.	2.	0.06	0.07	0.09	346.
27 MAR 84 -	855	9.91	112.(127.)	0.42	0.1875	5.3	238.	25.	23.	0.05	0.08	0.09	354.
27 MAR 84 -	1655	8.32	42.(45.)	0.26	0.2031	4.9	238.	26.	9.	0.01	-0.03	0.03	228.
28 MAR 84 -	55	8.30	38.(42.)	0.25	0.1875	5.3	251.	26.	5.	0.04	0.08	0.09	357.
28 MAR 84 -	855	10.10	96.(90.)	0.39	0.1094	9.1	266.	35.	23.	0.02	0.09	0.10	10.
28 MAR 84 -	1655	7.92	76.(74.)	0.35	0.1094	9.1	270.	22.	17.	0.04	0.01	0.04	305.
29 MAR 84 -	55	8.75	671.(645.)	1.04	0.2188	4.6	268.	30.	133.	0.02	0.05	0.06	1.
29 MAR 84 -	855	10.42	3400.(3174.)	2.33	0.1094	9.1	254.	27.	915.	0.02	-0.12	0.12	213.
29 MAR 84 -	1655	8.46	4493.(3543.)	2.68	0.0781	12.8	269.	25.	1061.	-0.36	-0.21	0.42	146.
30 MAR 84 -	55	9.62	5874.(4956.)	3.07	0.0781	12.8	275.	30.	1246.	-0.04	-0.23	0.23	196.
30 MAR 84 -	855	10.18	6968.(5893.)	3.34	0.0781	12.8	264.	22.	2202.	0.01	-0.16	0.16	207.
30 MAR 84 -	1655	7.89	3041.(2931.)	2.21	0.0781	12.8	277.	24.	997.	-0.02	-0.12	0.12	196.
31 MAR 84 -	55	9.65	3079.(2864.)	2.22	0.0781	12.8	273.	23.	1174.	0.05	0.04	0.07	333.
31 MAR 84 -	855	9.58	1832.(1734.)	1.71	0.0781	12.8	268.	21.	566.	0.05	-0.01	0.05	287.
31 MAR 84 -	1655	7.64	783.(769.)	1.12	0.0938	10.7	279.	24.	361.	0.05	-0.02	0.05	269.
1 APR 84 -	55	9.88	537.(489.)	0.93	0.0938	10.7	267.	34.	123.	0.07	0.11	0.13	352.
1 APR 84 -	855	9.19	512.(495.)	0.91	0.0938	10.7	281.	27.	160.	0.04	0.00	0.04	301.
1 APR 84 -	1655	7.63	282.(277.)	0.67	0.0938	10.7	265.	21.	95.	0.04	0.06	0.07	352.
2 APR 84 -	55	10.13	227.(225.)	0.60	0.0938	10.7	269.	42.	67.	0.06	0.08	0.10	351.
2 APR 84 -	855	8.71	182.(175.)	0.54	0.1094	9.1	273.	36.	57.	0.03	0.03	0.04	337.
2 APR 84 -	1655	7.82	80.(78.)	0.36	0.0938	10.7	273.	21.	25.	0.06	0.09	0.11	353.

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - [illegible] JUNE 198[illegible]

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	θ_D
3 APR 84 -	55	10.30	111.(92.)	0.42	0.1094	9.1	272.	46.	37.	0.05	0.10	0.11	358.
3 APR 84 -	855	8.33	69.(70.)	0.33	0.1250	8.0	273.	32.	19.	0.05	0.03	0.05	327.
3 APR 84 -	1655	8.13	26.(29.)	0.20	0.1094	9.1	275.	25.	7.	0.02	0.07	0.07	11.
4 APR 84 -	55	10.39	42.(46.)	0.26	0.0938	10.7	284.	58.	8.	0.07	0.05	0.09	332.
4 APR 84 -	855	7.96	19.(23.)	0.18	0.1094	9.1	278.	37.	6.	0.06	0.00	0.06	292.
4 APR 84 -	1655	8.54	19.(21.)	0.17	0.0938	10.7	261.	30.	5.	0.03	0.06	0.06	359.
5 APR 84 -	55	10.32	42.(42.)	0.26	0.2500	4.0	297.	32.	11.	0.05	-0.02	0.05	271.
5 APR 84 -	855	7.74	392.(391.)	0.79	0.1875	5.3	287.	24.	126.	0.03	0.02	0.04	328.
5 APR 84 -	1655	9.00	1141.(1076.)	1.35	0.1719	5.8	287.	28.	301.	-0.01	0.12	0.12	31.
6 APR 84 -	55	10.08	626.(598.)	1.00	0.1250	8.0	247.	36.	119.	0.03	0.06	0.07	356.
6 APR 84 -	855	7.47	198.(189.)	0.56	0.1094	9.1	262.	33.	35.	0.04	0.00	0.04	290.
6 APR 84 -	1655	9.24	250.(230.)	0.63	0.1094	9.1	271.	23.	61.	0.07	0.04	0.08	324.
7 APR 84 -	55	9.66	351.(314.)	0.75	0.0938	10.7	256.	31.	102.	0.04	0.03	0.05	329.
7 APR 84 -	855	7.51	211.(204.)	0.58	0.0938	10.7	267.	32.	80.	0.06	0.04	0.07	331.
7 APR 84 -	1655	9.59	422.(407.)	0.82	0.0781	12.8	272.	33.	174.	0.05	0.07	0.09	345.
8 APR 84 -	55	9.20	399.(370.)	0.80	0.0781	12.8	275.	27.	138.	0.04	0.02	0.04	319.
8 APR 84 -	855	7.78	279.(263.)	0.67	0.0781	12.8	279.	23.	100.	0.06	0.02	0.06	310.
8 APR 84 -	1655	9.89	806.(751.)	1.14	0.1563	6.4	241.	28.	121.	0.04	0.01	0.04	314.
9 APR 84 -	55	8.89	983.(881.)	1.25	0.1406	7.1	251.	19.	217.	0.05	-0.03	0.06	263.
9 APR 84 -	855	8.51	793.(765.)	1.13	0.1094	9.1	263.	26.	217.	0.05	0.05	0.07	337.
9 APR 84 -	1655	9.97	1486.(1349.)	1.54	0.1094	9.1	259.	22.	409.	0.07	-0.01	0.07	291.
10 APR 84 -	55	8.42	700.(661.)	1.06	0.1250	8.0	265.	27.	172.	0.03	-0.02	0.03	259.
10 APR 84 -	855	9.13	1036.(962.)	1.29	0.0938	10.7	268.	33.	184.	0.03	0.00	0.03	296.
10 APR 84 -	1655	9.75	1136.(1010.)	1.35	0.1094	9.1	252.	27.	227.	0.05	-0.04	0.07	257.
11 APR 84 -	55	7.90	713.(664.)	1.07	0.1094	9.1	263.	31.	162.	0.02	-0.02	0.03	253.
11 APR 84 -	855	9.81	774.(711.)	1.11	0.1094	9.1	257.	27.	160.	0.00	0.03	0.03	21.
11 APR 84 -	1655	9.13	575.(549.)	0.96	0.1406	7.1	262.	36.	131.	0.04	-0.02	0.04	262.
12 APR 84 -	55	7.72	213.(220.)	0.58	0.0938	10.7	272.	33.	51.	0.04	0.01	0.04	314.
12 APR 84 -	855	10.41	757.(666.)	1.10	0.1250	8.0	261.	30.	189.	0.00	0.06	0.06	22.
12 APR 84 -	1655	8.48	933.(897.)	1.22	0.1250	8.0	276.	29.	257.	-0.01	0.01	0.01	66.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	
13 APR 84 -	55	8.06	555.(541.)	0.94	0.1094	9.1	261.	29.	170.	0.04	0.08	0.09	358.
13 APR 84 -	855	10.67	702.(642.)	1.06	0.1250	8.0	240.	26.	172.	0.00	0.07	0.07	28.
13 APR 84 -	1655	7.85	260.(244.)	0.65	0.1563	6.4	247.	50.	49.	0.03	-0.05	0.06	239.
14 APR 84 -	55	8.82	181.(181.)	0.54	0.1406	7.1	264.	19.	42.	0.02	0.07	0.08	12.
14 APR 84 -	855	10.59	289.(294.)	0.68	0.1250	8.0	271.	36.	60.	0.05	-0.01	0.05	286.
14 APR 84 -	1655	7.24	438.(446.)	0.84	0.0938	10.7	284.	31.	159.	0.03	-0.03	0.05	250.
15 APR 84 -	55	9.50	241.(236.)	0.62	0.0938	10.7	270.	29.	88.	0.01	0.07	0.07	21.
15 APR 84 -	855	9.96	410.(378.)	0.81	0.0938	10.7	272.	39.	98.	0.04	-0.03	0.05	264.
16 APR 84 -	55	10.24	401.(407.)	0.80	0.2188	4.6	237.	32.	49.	0.03	0.04	0.05	345.
16 APR 84 -	855	9.18	391.(367.)	0.79	0.1094	9.1	275.	31.	58.	0.05	0.01	0.05	307.
16 APR 84 -	1655	7.30	205.(198.)	0.57	0.1250	8.0	266.	25.	38.	0.04	0.02	0.05	316.
17 APR 84 -	55	10.68	252.(211.)	0.64	0.1250	8.0	256.	57.	49.	0.03	0.07	0.08	358.
17 APR 84 -	855	8.36	227.(219.)	0.60	0.1094	9.1	282.	36.	36.	0.02	0.02	0.03	343.
17 APR 84 -	1655	7.77	108.(101.)	0.42	0.1094	9.1	271.	31.	25.	0.03	0.10	0.11	9.
18 APR 84 -	55	10.78	193.(188.)	0.56	0.1094	9.1	286.	48.	39.	0.04	0.07	0.08	351.
18 APR 84 -	855	7.65	201.(195.)	0.57	0.1250	8.0	275.	26.	67.	0.02	-0.03	0.03	241.
18 APR 84 -	1655	8.59	68.(63.)	0.33	0.1094	9.1	262.	29.	16.	0.04	0.11	0.12	3.
19 APR 84 -	55	10.72	159.(164.)	0.50	0.1094	9.1	261.	44.	33.	0.02	0.07	0.07	7.
19 APR 84 -	855	7.38	199.(193.)	0.56	0.1875	5.3	248.	21.	40.	0.03	-0.01	0.03	266.
19 APR 84 -	1655	9.24	489.(473.)	0.88	0.1094	9.1	272.	32.	120.	0.06	0.09	0.11	350.
20 APR 84 -	55	10.13	436.(439.)	0.84	0.1250	8.0	260.	23.	121.	0.06	0.03	0.07	320.
20 APR 84 -	855	7.16	156.(157.)	0.50	0.1250	8.0	274.	26.	51.	0.04	0.01	0.04	313.
20 APR 84 -	1655	9.56	91.(94.)	0.38	0.1094	9.1	285.	31.	17.	0.05	0.05	0.07	343.
21 APR 84 -	55	9.38	71.(70.)	0.34	0.1250	8.0	256.	31.	15.	0.03	0.00	0.03	297.
21 APR 84 -	855	7.50	25.(27.)	0.20	0.1094	9.1	280.	31.	14.	0.05	0.00	0.05	296.
21 APR 84 -	1655	9.82	127.(131.)	0.45	0.1875	5.3	223.	28.	21.	0.08	0.07	0.11	333.
22 APR 84 -	55	8.82	420.(383.)	0.82	0.1406	7.1	248.	26.	103.	0.11	0.05	0.12	318.
22 APR 84 -	855	8.28	541.(515.)	0.93	0.1406	7.1	252.	20.	165.	0.08	0.04	0.09	323.
22 APR 84 -	1655	9.84	641.(617.)	1.01	0.1094	9.1	247.	23.	149.	0.04	0.05	0.06	344.

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	[illegible]
23 APR 84 -	55	8.41	95.(96.)	0.39	0.1406	7.1	254.	34.	19.	0.06	0.03	0.06	320.
23 APR 84 -	855	8.67	41.(42.)	0.26	0.1094	9.1	274.	27.	9.	0.05	0.07	0.09	350.
23 APR 84 -	1655	9.52	46.(47.)	0.27	0.0938	10.7	267.	45.	11.	0.03	0.01	0.04	317.
24 APR 84 -	55	8.00	39.(38.)	0.25	0.1094	9.1	283.	28.	13.	0.02	0.01	0.02	335.
24 APR 84 -	855	9.33	268.(262.)	0.65	0.1875	5.3	253.	23.	46.	0.06	0.03	0.07	323.
24 APR 84 -	1655	9.31	241.(234.)	0.62	0.1563	6.4	263.	21.	55.	0.05	0.04	0.07	331.
25 APR 84 -	55	7.99	227.(220.)	0.60	0.1250	8.0	246.	29.	62.	0.04	-0.01	0.04	280.
25 APR 84 -	855	9.80	212.(186.)	0.58	0.1250	8.0	253.	40.	48.	0.03	0.07	0.07	2.
25 APR 84 -	1655	8.82	175.(160.)	0.53	0.1250	8.0	271.	24.	30.	0.03	0.03	0.04	343.
26 APR 84 -	55	8.10	200.(181.)	0.57	0.1719	5.8	241.	27.	33.	0.09	0.09	0.13	339.
26 APR 84 -	855	10.13	682.(596.)	1.04	0.1406	7.1	252.	27.	90.	0.06	0.04	0.07	325.
26 APR 84 -	1655	8.46	822.(758.)	1.15	0.1094	9.1	274.	22.	272.	0.01	-0.04	0.04	216.
27 APR 84 -	55	8.49	360.(321.)	0.76	0.0938	10.7	271.	26.	106.	0.07	0.08	0.10	341.
27 APR 84 -	855	10.20	244.(229.)	0.62	0.1250	8.0	260.	30.	45.	0.03	0.07	0.08	2.
27 APR 84 -	1655	8.20	265.(257.)	0.65	0.1094	9.1	273.	25.	50.	0.02	0.02	0.03	337.
28 APR 84 -	55	8.87	139.(141.)	0.47	0.1094	9.1	261.	27.	34.	0.04	0.06	0.07	353.
28 APR 84 -	855	10.05	218.(211.)	0.59	0.1094	9.1	256.	30.	68.	0.04	0.04	0.05	341.
28 APR 84 -	1655	7.93	256.(259.)	0.64	0.1094	9.1	277.	25.	101.	0.03	-0.03	0.04	251.
29 APR 84 -	55	9.21	328.(304.)	0.72	0.0938	10.7	264.	20.	132.	0.07	0.11	0.13	354.
29 APR 84 -	855	9.74	450.(437.)	0.85	0.0938	10.7	271.	30.	173.	0.02	0.02	0.03	348.
29 APR 84 -	1655	7.61	315.(312.)	0.71	0.1094	9.1	267.	18.	100.	0.02	-0.01	0.02	268.
30 APR 84 -	55	9.54	192.(206.)	0.55	0.0938	10.7	270.	28.	62.	0.07	0.11	0.13	353.
30 APR 84 -	855	9.35	320.(295.)	0.72	0.0938	10.7	268.	24.	127.	0.05	0.01	0.05	311.
30 APR 84 -	1655	7.50	103.(100.)	0.41	0.1094	9.1	276.	25.	54.	0.05	-0.01	0.06	281.
1 MAY 84 -	55	9.81	118.(121.)	0.44	0.1094	9.1	268.	34.	37.	0.07	0.11	0.13	350.
1 MAY 84 -	855	8.87	83.(80.)	0.36	0.1094	9.1	279.	30.	22.	0.03	0.02	0.04	330.
1 MAY 84 -	1655	7.61	50.(51.)	0.28	0.1094	9.1	275.	22.	26.	0.06	0.02	0.06	318.
2 MAY 84 -	55	10.11	39.(38.)	0.25	0.1250	8.0	258.	43.	7.	0.00	0.03	0.03	22.
2 MAY 84 -	855	8.42	8.(10.)	0.11	0.1250	8.0	286.	34.	2.	0.08	0.03	0.08	316.
2 MAY 84 -	1655	7.83	6.(8.)	0.10	0.1094	9.1	280.	33.	2.	0.05	0.00	0.05	297.

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	
3 MAY 84 -	55	10.34	7.(10.)	0.11	0.1250	8.0	262.	50.	1.	0.01	0.11	0.11	18.
3 MAY 84 -	855	8.01	9.(10.)	0.12	0.1250	8.0	263.	32.	2.	0.03	0.02	0.04	331.
3 MAY 84 -	1655	8.21	4.(6.)	0.08	0.1094	9.1	271.	41.	1.	0.05	0.10	0.11	0.
4 MAY 84 -	55	10.42	16.(18.)	0.16	0.2500	4.0	234.	40.	7.	0.01	0.08	0.08	15.
4 MAY 84 -	855	7.71	209.(209.)	0.58	0.2188	4.6	277.	28.	39.	0.07	0.00	0.07	293.
4 MAY 84 -	1655	8.66	96.(103.)	0.39	0.1406	7.1	257.	21.	30.	0.10	0.05	0.11	320.
5 MAY 84 -	55	10.36	248.(252.)	0.63	0.1719	5.8	252.	30.	38.	0.01	0.00	0.01	284.
5 MAY 84 -	855	7.36	56.(60.)	0.30	0.1406	7.1	258.	25.	14.	0.05	-0.03	0.06	266.
5 MAY 84 -	1655	9.13	46.(47.)	0.27	0.0938	10.7	262.	28.	8.	0.05	0.01	0.05	309.
6 MAY 84 -	55	9.91	34.(34.)	0.23	0.0938	10.7	260.	41.	9.	0.01	0.04	0.04	17.
6 MAY 84 -	855	7.23	8.(11.)	0.12	0.0938	10.7	267.	39.	1.	0.05	0.00	0.05	294.
6 MAY 84 -	1655	9.55	8.(12.)	0.12	0.0938	10.7	279.	38.	3.	0.03	0.04	0.05	344.
7 MAY 84 -	55	9.41	6.(9.)	0.10	0.1094	9.1	292.	49.	1.	0.04	0.00	0.04	300.
7 MAY 84 -	855	7.62	4.(6.)	0.08	0.1250	8.0	263.	40.	1.	0.04	0.06	0.07	349.
7 MAY 84 -	1655	9.90	7.(8.)	0.10	0.0625	16.0	293.	55.	2.	0.03	0.04	0.05	344.
8 MAY 84 -	55	8.79	5.(8.)	0.09	0.0625	16.0	253.	37.	2.	0.04	0.02	0.04	320.
8 MAY 84 -	855	8.09	5.(6.)	0.09	0.0625	16.0	260.	38.	2.	0.00	0.05	0.05	29.
8 MAY 84 -	1655	10.02	229.(226.)	0.61	0.2031	4.9	304.	28.	56.	0.02	0.07	0.08	11.
9 MAY 84 -	55	8.20	28.(29.)	0.21	0.2031	4.9	271.	39.	4.	0.04	-0.01	0.04	286.
9 MAY 84 -	855	8.79	22.(28.)	0.19	0.1250	8.0	277.	33.	4.	0.05	0.08	0.09	354.
9 MAY 84 -	1655	9.79	41.(41.)	0.26	0.1406	7.1	240.	41.	5.	0.01	-0.01	0.02	247.
10 MAY 84 -	55	7.60	32.(32.)	0.23	0.1094	9.1	272.	23.	10.	0.05	-0.02	0.05	275.
10 MAY 84 -	855	9.45	24.(24.)	0.19	0.1094	9.1	277.	38.	8.	0.02	0.04	0.05	0.
10 MAY 84 -	1655	9.25	28.(30.)	0.21	0.1250	8.0	263.	32.	5.	0.03	0.04	0.05	348.
11 MAY 84 -	55	7.44	11.(12.)	0.13	0.1406	7.1	264.	29.	3.	0.00	0.02	0.02	22.
11 MAY 84 -	855	10.00	14.(16.)	0.15	0.0781	12.8	282.	60.	2.	-0.02	0.10	0.10	34.
11 MAY 84 -	1655	8.60	11.(15.)	0.14	0.2500	4.0	309.	37.	2.	0.05	0.07	0.09	350.
12 MAY 84 -	55	7.79	6.(7.)	0.10	0.0781	12.8	263.	29.	2.	0.04	0.09	0.10	3.
12 MAY 84 -	855	10.37	26.(36.)	0.20	0.2500	4.0	307.	59.	10.	0.05	0.08	0.09	353.
12 MAY 84 -	1655	8.01	13.(15.)	0.15	0.2500	4.0	305.	40.	4.	0.04	0.04	0.06	341.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - [illegible] JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	[illegible]
13 MAY 84 -	55	8.43	8.(8.)	0.11	0.0781	12.8	260.	36.	2.	0.05	0.10	0.12	0.
13 MAY 84 -	855	10.30	12.(17.)	0.14	0.1719	5.8	272.	41.	2.	0.05	0.06	0.08	346.
13 MAY 84 -	1655	7.47	13.(13.)	0.14	0.1094	9.1	274.	35.	2.	0.00	-0.04	0.04	206.
14 MAY 84 -	55	9.16	11.(12.)	0.13	0.1250	8.0	269.	42.	2.	0.01	0.11	0.11	22.
14 MAY 84 -	855	9.84	17.(20.)	0.17	0.2500	4.0	258.	46.	2.	0.04	-0.06	0.07	238.
14 MAY 84 -	1655	7.12	13.(15.)	0.14	0.1250	8.0	274.	36.	1.	0.08	0.00	0.08	295.
15 MAY 84 -	55	9.83	24.(26.)	0.19	0.2031	4.9	254.	44.	4.	0.03	0.12	0.12	11.
15 MAY 84 -	855	9.08	26.(26.)	0.21	0.1719	5.8	261.	33.	3.	0.03	0.01	0.04	319.
15 MAY 84 -	1655	7.20	24.(26.)	0.20	0.1094	9.1	277.	20.	9.	0.04	0.03	0.05	329.
16 MAY 84 -	55	10.34	40.(45.)	0.25	0.0938	10.7	272.	47.	13.	0.05	0.08	0.09	354.
16 MAY 84 -	855	8.45	68.(64.)	0.33	0.0938	10.7	267.	28.	22.	0.03	0.06	0.07	2.
16 MAY 84 -	1655	7.64	69.(66.)	0.33	0.0938	10.7	279.	19.	41.	0.02	0.05	0.06	2.
17 MAY 84 -	55	10.64	42.(40.)	0.26	0.0938	10.7	276.	57.	13.	0.04	0.11	0.12	6.
17 MAY 84 -	855	7.91	75.(74.)	0.35	0.1094	9.1	284.	28.	21.	0.02	0.05	0.05	359.
17 MAY 84 -	1655	8.33	36.(39.)	0.24	0.1094	9.1	270.	26.	9.	-0.02	0.06	0.06	45.
18 MAY 84 -	55	10.63	45.(49.)	0.27	0.1250	8.0	282.	39.	9.	0.03	0.01	0.03	317.
18 MAY 84 -	855	7.59	79.(76.)	0.36	0.1094	9.1	275.	25.	18.	0.04	0.00	0.04	301.
18 MAY 84 -	1655	8.98	226.(237.)	0.60	0.0938	10.7	270.	26.	41.	0.01	0.04	0.04	5.
19 MAY 84 -	55	10.20	712.(637.)	1.07	0.0938	10.7	268.	32.	281.	0.03	0.01	0.03	308.
19 MAY 84 -	855	7.23	315.(311.)	0.71	0.1094	9.1	281.	27.	102.	0.04	-0.01	0.04	281.
19 MAY 84 -	1655	9.31	99.(99.)	0.40	0.1094	9.1	276.	26.	21.	0.02	0.04	0.04	357.
20 MAY 84 -	55	9.61	97.(102.)	0.39	0.0938	10.7	269.	32.	30.	0.04	0.03	0.04	330.
20 MAY 84 -	855	7.39	66.(62.)	0.32	0.0938	10.7	278.	24.	29.	0.03	-0.01	0.03	276.
20 MAY 84 -	1655	9.66	71.(75.)	0.34	0.0938	10.7	278.	31.	33.	0.03	0.02	0.04	332.
21 MAY 84 -	55	9.06	60.(56.)	0.31	0.0938	10.7	265.	26.	22.	0.01	0.00	0.01	315.
21 MAY 84 -	855	7.80	61.(60.)	0.31	0.0938	10.7	273.	25.	22.	0.01	0.04	0.04	9.
21 MAY 84 -	1655	9.83	86.(79.)	0.37	0.0938	10.7	260.	37.	37.	0.01	0.04	0.04	3.
22 MAY 84 -	55	8.60	93.(95.)	0.39	0.0938	10.7	272.	27.	45.	0.04	0.02	0.04	318.
22 MAY 84 -	855	8.35	44.(45.)	0.27	0.1094	9.1	277.	25.	15.	0.07	0.06	0.09	336.
22 MAY 84 -	1655	9.76	34.(40.)	0.23	0.0938	10.7	272.	50.	11.	-0.01	0.03	0.04	43.

Table VII-2-4 (cont)

WAVE CLIMATE - GREEN HARBOR, MASSACHUSETTS - SEA DATA 635-12 23 FEB 1984 - 1 JUNE 1984

DATE	TIME	$\bar{h}$ (m)	E_T (cm^2)	$H_{1/3}$ (m)	Peak F (sec^{-1})	Peak T (sec)	α_o	$P(\alpha_o)$	E_P (cm^2)	$\bar{U}$ (m/sec)	$\bar{V}$ (m/sec)	C_s	C_D
23 MAY 84 -	55	8.16	38.(40.)	0.25	0.1094	9.1	275.	23.	14.	0.06	0.02	0.06	312.
23 MAY 84 -	855	8.79	24.(25.)	0.20	0.1094	9.1	277.	21.	10.	0.04	0.07	0.08	358.
23 MAY 84 -	1655	9.42	21.(18.)	0.19	0.1094	9.1	271.	42.	5.	0.04	0.15	0.16	10.
24 MAY 84 -	55	7.84	10.(13.)	0.13	0.1250	8.0	270.	30.	3.	0.07	0.04	0.08	323.
24 MAY 84 -	855	9.22	7.(8.)	0.11	0.0938	10.7	277.	36.	1.	0.02	0.03	0.04	355.
24 MAY 84 -	1655	9.15	7.(7.)	0.11	0.1094	9.1	274.	35.	2.	-0.04	0.00	0.04	121.
25 MAY 84 -	55	7.85	6.(6.)	0.09	0.1094	9.1	275.	32.	1.	-0.01	0.00	0.01	130.
25 MAY 84 -	855	9.62	8.(11.)	0.11	0.1250	8.0	290.	61.	1.	0.05	0.09	0.11	355.
25 MAY 84 -	1655	8.75	8.(11.)	0.11	0.1250	8.0	269.	31.	2.	0.06	0.11	0.13	356.
26 MAY 84 -	55	7.91	4.(16.)	0.08	0.1094	9.1	307.	58.	1.	0.02	0.09	0.10	15.
26 MAY 84 -	855	9.81	6.(9.)	0.10	0.0781	12.8	276.	69.	1.	0.05	0.06	0.08	347.
26 MAY 84 -	1655	8.39	3.(5.)	0.07	0.1094	9.1	281.	39.	0.	0.05	0.06	0.08	345.
27 MAY 84 -	55	8.26	3.(5.)	0.07	0.0781	12.8	257.	49.	1.	0.06	0.11	0.12	357.
27 MAY 84 -	855	9.89	6.(9.)	0.10	0.0625	16.0	298.	54.	1.	-0.02	0.05	0.05	46.
27 MAY 84 -	1655	8.19	6.(7.)	0.10	0.1250	8.0	269.	36.	1.	-0.01	-0.02	0.02	163.
28 MAY 84 -	55	8.75	7.(6.)	0.10	0.0625	16.0	270.	47.	2.	0.05	0.11	0.13	1.
28 MAY 84 -	855	9.82	10.(12.)	0.12	0.1094	9.1	290.	60.	1.	0.01	-0.02	0.03	234.
28 MAY 84 -	1655	7.94	9.(8.)	0.12	0.0781	12.8	266.	45.	1.	0.00	-0.04	0.04	208.
29 MAY 84 -	55	9.20	135.(130.)	0.46	0.2500	4.0	279.	36.	53.	0.02	0.03	0.04	350.
29 MAY 84 -	855	9.53	229.(235.)	0.61	0.2188	4.6	286.	21.	65.	0.05	-0.04	0.06	256.
29 MAY 84 -	1655	7.66	53.(57.)	0.29	0.1563	6.4	266.	18.	17.	0.05	0.04	0.06	334.
30 MAY 84 -	55	9.59	68.(71.)	0.33	0.1875	5.3	252.	20.	15.	0.06	0.12	0.14	360.
30 MAY 84 -	855	9.18	95.(86.)	0.39	0.1406	7.1	249.	26.	14.	0.02	-0.03	0.04	243.
30 MAY 84 -	1655	7.56	26.(29.)	0.20	0.1563	6.4	249.	40.	4.	0.02	0.04	0.05	356.
31 MAY 84 -	55	9.94	24.(25.)	0.20	0.2500	4.0	295.	52.	6.	0.01	0.06	0.06	20.
31 MAY 84 -	855	8.70	39.(40.)	0.25	0.2500	4.0	302.	29.	12.	0.02	0.03	0.04	354.
31 MAY 84 -	1655	7.69	20.(19.)	0.18	0.1406	7.1	262.	26.	3.	0.01	0.01	0.02	340.
1 JUN 84 -	40	10.36	19.(29.)	0.18	0.0938	10.7	288.	57.	2.	0.03	0.09	0.09	8.
Mean		8.92	398.(368.)	0.59		9.2	269.		109.	0.03	0.03		
SD		0.85	816.(729.)	0.55		2.6	15.		229.	0.04	0.05		